AN EXAMINATION OF AGREEMENT TYPE, FIRM SIZE AND OTHER FACTORS AFFECTING THE COMMERCIALIZATION OF AIR FORCE TECHNOLOGY

THESIS

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Robert S. Widmann

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Abstract

In the last decade, there has been increasing interest in the transfer of technology from the federal government for use in the private sector to increase economic growth and improve the United States' competitiveness in world markets. The government employs two significant mechanisms for promoting commercialization of new technology: Cooperative Research and Development Agreements (CRDAs) and Small Business Innovative Research (SBIR) contracts.

The first fundamental difference between a CRDA and a SBIR is that the former involves private firms of all sizes in the technology transfer process, while the latter is reserved exclusively for small businesses (generally defined as 500 employees or less). The contrast between these mechanisms presents a unique opportunity to test the older, Schumpetarian hypothesis that large firms are better innovators (developers of technology) against more recent evidence that suggests smaller firms possess greater innovative ability. The second fundamental difference between CRDAs and SBIRs results from the nature of their governing agreements. The CRDA promotes technology transfer through technical assistance, access to government facilities, and direct involvement of government specialists without any direct transfer of funds to the private firm. On the other hand, the SBIR promotes innovation through direct funding of research efforts through a contracting process that selects potentially successful projects, but minimizes direct government involvement with the contractor. Finally, while research supports firm

size and agreement type as significant factors affecting the firm's results, it is recognized that many other factors play a role in the successful commercialization of technology transfer.

The objective of this thesis is to determine if a significant difference in the innovative strength of businesses exists when factors such as firm size, agreement type and other firm attributes are considered. Sample data for this study was collected by a telephone survey from firms selected from the Air Force population of CRDAs and SBIRs for Fiscal Years 1991-1993. The design of this survey, based on one used by Dr. Robert Berger to study SBIR outcomes, determines the degree of commercialization of the firm's product resulting from its agreement with the Air Force. This determination is then employed as a measure of the innovative ability of the firm. Additionally, the survey collects several variables describing the state of the firm at the inception of the SBIR or CRDA, such as firm size, product orientation, and prior business experience in order to assess their correlation with the commercialization outcome.

This researcher found that the degree of commercialization differed significantly between the two contract mechanisms. Moreover, firm size possessed a negative relationship with the degree of commercialization for CRDAs. Additionally, the more mature the technology transferred under both SBIRs or CRDAs, the greater the degree of commercialization.

AN EXAMINATION OF AGREEMENT TYPE, FIRM SIZE AND OTHER FACTORS AFFECTING THE COMMERCIALIZATION OF AIR FORCE TECHNOLOGY

I. Introduction

Statement of Purpose

In the last fifteen years, there has been an increasing emphasis on utilizing Department of Defense (DoD) resources (and those of other federal agencies) to stimulate the domestic economy, increase economic growth, and improve the United States' competitiveness in world markets. Congress has enacted several pieces of legislation to promote the transfer of technology to the private sector for the purpose of commercializing new technologies. One such law created the Cooperative Research and Development Agreement (CRDA) which promotes technology transfer through technical assistance, access to government facilities, and direct involvement of government research employees working with private firms. However, unlike typical research and development (R&D) contracting vehicles, the law prevents CRDA recipients from receiving direct government funding for their projects. Other legislation created the Small Business Innovative Research (SBIR) contract that promotes the commercialization of technologies by small business through direct funding of research efforts with little access to other government resources.

By enacting these laws, Congress' intent was to improve the standard of living for United States citizens by using innovative technology to enhance productivity, create new industries, and generate employment opportunities (5:52). In order to ensure that the

processes Congress created are working, the results of these laws must be measured. Specifically, the contribution to the economy of the innovative activity induced by SBIRs and CRDAs needs to be quantified. One clear measure of success is the amount of new economic activity induced by the new technology, as represented by changes in the firm's revenues (17). However, isolating and identifying revenues related to a very evolutionary and fluid event is very difficult. An alternative measure that captures the technology transfer result evaluates the commercial outcome along a spectrum ranging from no sales occurred as a result of the transfer, through potential for future sales, to sales have occurred utilizing a process or product resulting from the new technology. Though qualitative in nature, the measure captures an essential element of government induced innovation: whether or not the technology contributed to the US economy through increased economic output at the time of the data collection.

In an environment of limited government resources, maximum return on technology investment is necessary. Therefore, optimal government policy should dictate that federal technology resources be directed to those firms that possess the necessary abilities to develop and commercialize the technology. To formulate this policy, government leaders require knowledge of the factors affecting the commercialization outcome of a transfer event. Once identified, it is then possible to formulate government policy that optimizes the probability of commercializing government technology.

A large stream of research, beginning with Joseph Schumpeter in the 1930's, identifies potential factors influencing commercial innovation in the private sector of the economy. With the recent dramatic increase in the federal government's role in stimulating private firm technology development, the question that must be asked is: What factors influence the outcome of technology innovation flowing from the federal government to the private sector of our economy? Such research provides crucial information to DoD and Air Force decision-makers so they may tailor technology transfer

programs and select participating firms capable of successfully commercializing military technology.

The purpose of this research effort is twofold. The first purpose is to test the influence of five factors identified from prior research literature as influencing commercial innovation in the private economy. The factors are firm size, prior innovative experience, prior experience in the technology area, the maturity of the technology, and the contract mechanism employed by the government to stimulate the innovation. This study examines the influence of these business characteristics on the commercialization of technology originally developed for or by the US Air Force. The intent of this research is to discover if these factors influence successful commercial innovation when a government agency, specifically the Air Force, is involved in the process through the use of CRDA or SBIR vehicles. The second purpose of this research is to gather anecdotal data regarding the experiences of firms negotiating and carrying out commercial innovation in conjunction with a CRDA or SBIR with the Air Force. Identifying other factors will provide directions for future research in this area.

Definitions

Before formulating specific problem statements and hypotheses, the terms used in the formulation require exact definitions to convey the proper meaning.

Invention: The process of arriving at an idea for a device, product, or process and demonstrating its feasibility (13:3).

Innovation: Changes in the methods of supplying commodities. The term "methods" means the introduction of new combinations of inputs. This Schumpeterian definition of innovation must be separate and distinct from the term invention to understand the critical importance of innovation to technology transfer and economic development. While inventions and inventors are typically celebrated, the act of

innovation makes the invention practical and useful. To quote Schumpeter, "Economic leadership in particular must be distinguished from "invention." As long as they are not carried into practice, inventions are economically irrelevant. And to carry any improvement into effect is a task entirely different form inventing it..." Moreover, innovation employs technology for multiple uses. Innovation is the process that allows technology developed for a DoD application to be employed in another instance for a purely commercial application (34:8).

Commercialization: Innovation for profit. The development of a technology into a product or process to a degree that it (at least temporarily) is in demand in a marketplace.

Technology: The conception and/or demonstration of the capability of performing a specific elementary function using new or untried concepts, principles, techniques or materials, or the development of new manufacturing, fabrication, or processing techniques (14:157).

Technology Transfer: Disseminating information, matching technology with needs, and creative adapting of items to new uses (17:4).

Technological Change: A change involving a shift in the production function (29:343).

Specific Problem

The objective of this thesis is to determine the impact of several business characteristics on the commercialization of technology transferred from the federal government, specifically the United States Air Force (USAF). Past research identifies several factors that influence firm innovation, while also employing several different measures of innovation. These studies measure innovative ability using various metrics such as the number of patent citations, the return on investment, or the number of

commercial products marketed (1,2,4). This study will measure innovative ability as the degree of commercialization of transferred technology achieved by firms working with the USAF.

This study evaluates the factors of firm size, prior innovation experience, prior technology experience, and the maturity of technology for significance in predicting the degree of commercialization. Additionally, the existence of two methods of technology transfer (CRDAs and SBIRs) allows a comparison of their commercialization outcomes to determine if a significant difference exists between them. Moreover, comparisons of outcome by firm size, both within transfer process method (CRDAs or SBIRs) and across methods (CRDAs and SBIRs), can be made. Further stratification of the data along technology type or product type can be used to remove extraneous variables. For example, the degree of commercialization of small and large firms engaged specifically in the development of electrotechnology under CRDAs will be evaluated for significant differences. Such comparisons potentially recognize subpopulations that possess unique factors influencing their outcomes from the technology transfer process. Furthermore, firm characteristics may be significantly related to one subpopulation but not another. For example, the size of the firm may be significantly related to the outcome of the technology transfer process for CRDA participants while not significantly related to outcomes for SBIR contractors.

Hypotheses

This study's first hypothesis tests if a significant difference exists between the degree of commercialization of SBIR contracts and the degree of commercialization for CRDA agreements. The direction of this difference cannot be postulated. The SBIR process involves milestones where government personnel review contractor progress before approving further funding, ensuring only promising research proceeds to

development and potential commercialization. On the other hand, CRDAs do not have a formal review process, but rather allow the marketplace, through contractor decisions to commit resources to the project, to determine promising innovations.

The second hypothesis tested in this study examines the relationship between firm size, large or small, and the degree of commercialization of the firm's product developed with technology transferred from the Air Force. Early research suggests that large firms under oligopolistic conditions better innovate, while later research suggests that small firms adapt new technologies as commercial products to capture markets dominated by larger firms with established products; essentially creating new markets and making old products obsolete. This study evaluates two measures of size, an absolute measure, the total number of firm employees, and a relative measure of size, the market share possessed by the firm in the sample project's technology area

The third hypothesis tested in this study examines the relationship between a firm's prior innovation experiences and the commercialization of products resulting from technology transfer with the federal government. Research and development for the purpose of marketing a commercial product requires significant resources such as business, marketing, legal, and contractual expertise beyond the technical knowledge associated with a specific product. This research proposes that a firm's expertise in these areas influences the outcome of its commercialization effort. Moreover, involving the federal government in the innovation process requires additional resources for negotiating an innovation agreement and managing the joint project.

The fourth hypothesis tested in this study examines the relationship between a firm's prior experience in the technology area of the innovation and the commercialization of products resulting from technology transfer with the federal government. Past research addresses this question from two different perspectives. First, some research argues that firms possessing a history in a technology area are better positioned to exploit advances in

that field. Moreover, learning curve theory reinforces this idea that as a firm learns from past experiences, it applies its innovative efforts more effectively. On the other hand, other research argues that technological advances threaten existing product market shares, so that firms established in a technology are less inclined to pursue technological advances.

The fifth hypothesis tested in this study examines the relationship between the maturity of the technology involved in the innovation agreement and the commercialization of the product resulting from the agreement. Current literature focuses on the maturity of technology in the product's life cycle. Firms experience increasing revenues as a product is introduced to a market, and economies of scale in production are realized. Eventually, new innovations make older products obsolete, causing the firm to discontinue the production of the older product. This research focuses on the maturity of the technology as applicable to the innovating firm's product. The more mature the technology as realized by the acquiring firm, the more readily adaptable it is to new products and markets. Therefore, this researcher predicts a positive relationship between the maturity of the technology and the degree of commercialization of the technology realized from the transfer.

In order to evaluate the data collected in light of the five hypotheses given above, this thesis examines the causal relationship between firm attributes and the degree of commercialization by using multiple regression analysis. Stratifying the data along the agreement type provides additional insight for the optimization of federal technology. The results of the five hypotheses above applied to this stratification of the data by agreement type determines the samples used for the regression.

The following chapters will develop the argument for this study's hypotheses, test their usefulness, and present the results of these tests. Chapter Two reviews the argument demonstrating the importance of technological innovation to economic growth. It also examines previous research supporting the inclusion of the five independent variables

employed in this study. Lastly, Chapter Two presents the development of the dependent variable used in this study. Chapter Three explains the methodology utilized in this study to examine the effects of the five variables on the degree of commercialization. Chapter Four presents the results of this study, while Chapter Five interprets their meanings and suggests future research possibilities.

II. Literature Review

Introduction

This literature review begins with an examination of the development of the technology innovation theory that leads to current research regarding the factors that affect commercial innovation. Next, it focuses on previous research supporting the inclusion of the five independent variables tested in this study. The literature review concludes with an examination of the proposed measure used to gauge the success of the technology transfer process. It also provides support for the decision to use the ordinal degree of commercialization as this study's dependent variable.

Background

Scherer presents Schumpeter's ideas regarding economic growth resulting from technology innovation in three major ideas. First, capitalist economies such as the economy of the United States evolve from a process of "creative destruction" in which old products and industries are continuously displaced by new products and industries. The driving force behind this change is technological innovation. Second, the gains in per capita real income in industrialized capitalist economies are directly attributable to technological progress. Moreover, the dynamism of these economies results from the movement of new technologies through the marketplace; technological innovation allows for increased output and income in the economy (35: vii).

Schumpeter lists three optimal conditions for technological innovation. One, monopoly power or the availability of discretionary funds for research and development is the most conducive business environment for technological innovation. Two, large firms better execute R&D programs than do smaller firms. Three, more diversified firms possess greater opportunities for innovation than do more focused firms (35:169).

Understanding Schumpeter's vision of technology-driven economic growth begins with the concept of the production function. Economists generally agree that economic growth is driven by two basic factors. First, the amount of output of an economy results from the quantity of the resource inputs (labor, capital, and natural resources) used for production in the economy. The second factor, the state of technical knowledge, affects the efficiency of the use of the input resources and is most pertinent to this study. The effect on output by these two factors can be expressed as the function:

$$\underline{Y} = \underline{A} * f(\underline{K}, \underline{L}, \underline{R}) \tag{1}$$

where

$\underline{Y}$ = Level of Output

$\underline{A}$ = Level of Technology

$\underline{K}$ = Quantity of Capital

$\underline{L}$ = Quantity of Labor

$\underline{R}$ = Quantity of Natural Resources

The production function links the amount of output produced in an economy to the input of factors and the state of technical knowledge (9:697-732). In the short run, the production function generally assumes a given level of capital, material resources, and a fixed level of technology. In other words, in the short run, the output of the economy varies only with the level of employment. The declining slope of the production function in the graph below depicts diminishing returns (output) for increasing amounts of input (labor) (29:75-79).

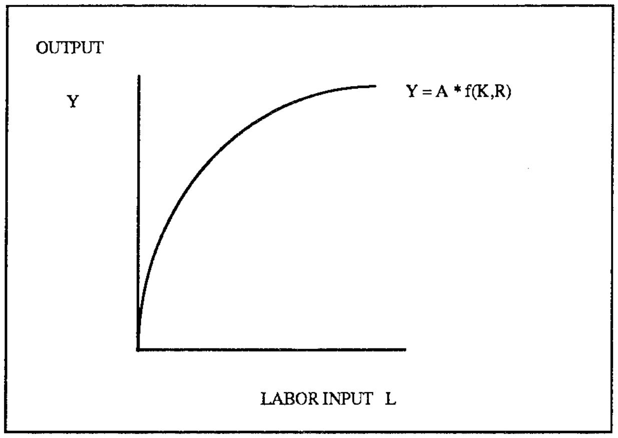

FIGURE 1 Short Run Production Function

Relaxing the short run assumption in the graph below shows the effect of an increase in capital inputs, resources, or an improvement in the level of technology on the production function. The upward shift of the production function indicates that for the same amount of labor, per capita output can be increased. In other words, providing added productive machinery or new and improved production technology increases the economy's output for the benefit of all consumers of that output (29:75-79).

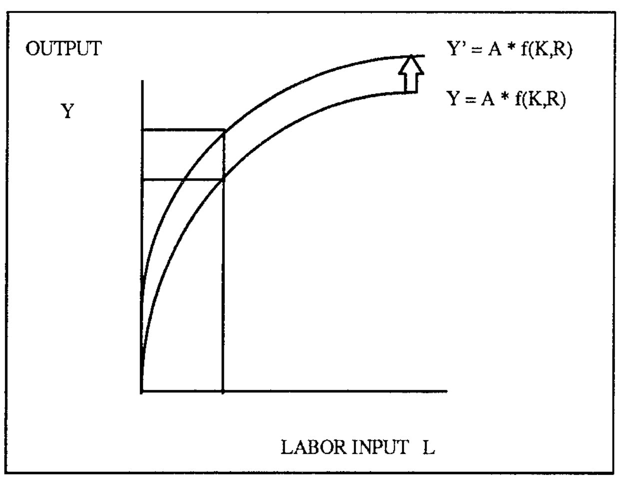

FIGURE 2 Production Function with Short Run Assumption Relaxed

The influence of the level of technology on the productive output of the economy cannot be overemphasized. A study by Robert Solow found that, historically, 80% of the growth in output per labor hour between 1909 and 1949 was due to technical progress. Additionally, Edward Denison found that of the 2.9% average annual rate of growth experienced by the US economy between 1929 and 1982, over 35% is attributed to technical progress (9:702). The level of technology, A, in the production function above, is a parameter whose value determines the output potential associated with specific quantities of the input factors. While it is a relatively simple idea that increasing the level of technology expands the possible frontier of economic output, some also argue that technological improvement may directly stimulate output.

Technological change that requires new capital equipment stimulates investment. Increased investment expands aggregate demand, which in turn results in a new equilibrium level of output. Frederick M. Scherer offers the following example of this phenomenon:

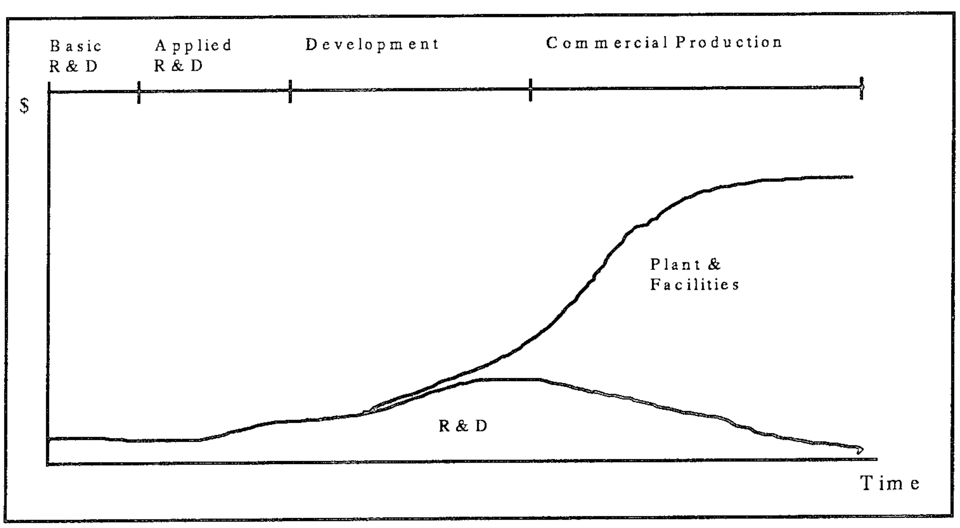

FIGURE 3 DuPont's Investment in the Development of Nylon

The curves above illustrate DuPont's investment in the development of nylon fiber over time from its initial discovery in 1930 ($50,000), through its development in the next decade ($1,000,000), to full-scale commercial production in the later 1930's and early 1940's ($44,000,000). New nylon technology resulted in massive private investment for its commercial development (34:4). DuPont's increased investment, like investment in many new technologies over time, increased aggregate demand. Increased aggregate demand establishes a new equilibrium level for output and income.

Schumpeter developed his ideas with the private sector economy in mind. However, DoD R&D can offer similar economic stimulus if promising technologies transition from federal control to the private sector. While most accept Schumpeter's concept of technological innovation as a factor contributing to economic growth, the optimal conditions cited by Scherer continue to create controversy today. A great deal of past private firm innovation research focuses on Schumpeter's three conditions: (1) monopoly power; (2) large firm innovation; and (3) diversified firm innovation. This research looks at firm innovation when the federal government, specifically the US Air Force, plays a role in the process. While focusing primarily on the issue of firm size, this research also examines to a lesser degree how government policy and actions mitigate the conditions of monopoly power and firm diversification through contract type. In addition to these conditions, the factors of innovation experience, technology experience, and the maturity of technology are examined for influence on the technological innovation of the firm. In order to better develop these factors, past research on firm size, contract type, innovation experience, technology experience, and the maturity of technology are examined.

Firm Size

Optimal firm size for innovation remains a contentious issue in current research. A great deal of literature argues for either large or small firms. Moreover, Schumpeter's idea of firm size either in absolute terms such as employment or annual sales, or in relative terms such as market share or sales per employee begs definition. The results from past research are presented below, first favoring large firms and second favoring small firms.

Large Firm Innovation. Schumpeter's basic argument favoring large firm innovation identifies the need for the firm to continue to innovate to fend off competition and maintain or increase market share (26:215). This drive relates strongly to the concept of monopoly power. A firm that brings an innovative product to market first enjoys a temporary advantage over competition in the form of extraordinary profits and market share. By continuously innovating, large firms can maintain or increase this advantage. Such a competitive strategy, referred to as Schumpetarian competition, recognizes that firms no longer compete on market-price, but rather market share (26:38). A firm that fails to innovate faces a loss of market share due to obsolescence. According to Schumpeter, due to its sheer size, the large firm brings greater financial resources and the ability to martial greater R&D resources to compete for market share in a manner small firms cannot (35:58).

Some recent research supports this theory. Scherer points out that very large industrial firms conduct a proportionately greater share of R&D than do smaller firms. However, this measure focuses on input to R&D rather than output from R&D. The only output measure Scherer finds that supports large firm innovation is in the number of patents, which exceeds that of smaller firms in both relative and absolute terms (34:237).

Acs and Audretsch find that large firms maintain an innovative advantage when the Schumpetarian tenets of imperfect competition and high barriers to entry exist in the marketplace. In this case, the authors employ the number of innovations as identified by

the US Small Business Administration (SBA) as their output measure (1:573). In another study, the same authors found that firms classified as "low-technology," based on the ratio of their R&D inputs to their annual value of sales, experience increasing returns to firm size when measuring the number of firm innovations. Again, high barriers to entry exist due to the capital intensive nature of the industry (4:743).

Mansfield finds that in the presence of three specific conditions, the four largest firms in an industry account for a relatively larger share of the innovations in that market. One, innovations require relatively costly investments (high barriers to entry). Two, economies of scale require at least a minimum sized firm to profitably employ the technology (again, high barriers to entry). Finally, larger firms innovate more under the conditions of a high four firm concentration ratio (22).

Small Firm Innovation. Transferred technology provides a starting point for firms to begin new product development. Recent research documents the ability of smaller firms to innovate to develop markets for new technologies. Advocates of small business point out that small businesses represent the largest area of job growth in the United States economy. Additionally, the small business sector is recognized as an important component of the second-tier manufacturing base supporting large contractors with the Department of Defense (DoD).

While the federal government generally recognizes their importance through programs such as the Small Business Administration (SBA), it expends very little effort to promote technology transfer opportunities to small businesses. For instance, federal law requires that DoD set aside a small portion (0.15% in FY96) of its R&D funding specifically for CRDAs with small businesses. However, a review of the CRDA recipient's for fiscal years 1991 through 1993 reveals that the actual number of CRDAs with small businesses barely exceeds this minimum threshold. SBIR program funding for FY93 totaled $130 million out of a total federal R&D budget of $36 billion (3:F12;

28:149). Moreover, little research exists documenting the performance of small firms engaged in technology transfer in general, and in particular regarding technology transfer with the federal government.

The federal government demonstrates interest in supporting technology transfer to small businesses through two methods of engaging small firms in R&D activities. The first method manifests itself primarily in goals for the direct expenditure of federal funds through the award of contracts to small businesses. Additionally, special programs and policies, such as the 8(a) program promote and nurture federal contracts with small businesses by setting aside specific contracts reserved only for small business bids. The Small Business Innovative Research (SBIR) program, created by the Small Business Innovation Development Act of 1982, encourages technological innovation by small businesses and offers an avenue for commercializing the technology developed under its auspices.

The second method of promoting technology transfer to small businesses involves non-cash support through non-contractual agreements defined by several Federal Statutes and Executive Orders. For example, the University and Small Business Patent Procedure Act first gave small businesses the right to retain patents for technology developed with government funding. The Federal Technology Transfer Act of 1986 amended the Stevenson-Wydler Technology Innovation Act of 1980 allowing federally owned and operated laboratories to enter into non-contractual agreements called Cooperative Research and Development Agreements (CRDAs) with private firms specifically for the purpose of engaging in technology transfer. The Act gives preference to small businesses. Lastly, the Small Business Research and Development Enhancement Act of 1992 created the Small Business Technology Transfer Program (STTR) that directs increasing percentages [.05% in FY94 ($24 million), .10% in FY95 ($48 million) and .15% in FY96

($72 million)] of five federal agencies' budgets (including the DOD's) toward cooperative agreements with small business (3:F12-F14).

Promoters of technology transfer tout it as a means of aiding small business' efforts to become more competitive by transferring government-held knowledge to the private sector for commercial use. The flurry of legislation in the last decade demonstrates congressional interest in this area; however, the DOD's R&D program faces increasing cuts. The budget dropped from $41 billion in 1989 to $36 billion in 1993 and is expected to drop further to approximately $30 billion by 1997 (28:149). The total Air Force SBIR budget for FY93 was only $130 million (3:F12). Moreover, the total portion of the federal government's R&D budget set-aside for technology transfer is minuscule at only 0.5% of each agencies' total R&D budget (32:22). These cuts in funding threaten the nascent efforts to promote technology transfer to small businesses. This indicates that as available funds for technology transfer shrink, policy makers must ensure that available funds are used effectively.

While the funding for technology transfer to small businesses shrinks, the evidence demonstrating small firm advantages in R&D grows. For the last 15 years, much of the research on the private sector's ability to utilize technology for commercial innovation focuses on small firms. Research supporting the innovative abilities of small firms now largely supplants the original Schumpetarian hypothesis that large firms engaging in imperfect competition best promote innovation (1; 2; 4). Studies show that small firms competing in highly innovative industries, dominated by large firms generate substantially more innovations than large firms (1:567;2). The Small Business Administration's (SBA) definition for innovation is, "...A process that begins with an invention, proceeds with the development of the invention, and results in the introduction of a new product, process or service to the market-place." (2:679).

Additionally, models suggest that while small firms tend to make leaps to new technologies, large firms tend to innovate by adding onto existing technologies (31:25; 33:412). Obviously, a large firm's vested interest lies in servicing a well-developed market for their current goods. On the other hand, in order to break into a market, a small firm must offer a product or service that is unique from those offered by their larger, established competitors (2:679). Additionally, labor-intensive, new product development better suits small firms with a high concentration of skilled labor rather than large capital-intensive firms, set up for mass production (1:571; 2:679). Another perspective offers that small firms innovate better than large firms in high technology industries that require only small leaps from existing technology to innovate (4:743). Large capital-intensive industries dominate low technology areas. Markets in low technology areas require substantial innovative leaps as well as large amounts of capital to bring new, technologically different products to market. The large firm's access to greater resources better suits it for innovation in low technology areas. Finally, research shows that small firms can act quicker to take advantage of technology innovation than can large firms (2:687). This research poses serious questions for policy-makers deciding the ratio of allocation of R&D funds between large and small firms.

Generally, the federal government develops leading edge technology and explores basic research questions economically infeasible for private firms or universities to undertake. Research concludes that much of this basic R&D would not exist without massive federal spending since the private sector generally underinvests in R&D (39:54). The research cited above strongly suggests that small businesses are well suited to engage in basic R&D. Besides basic research, much federal R&D money focuses on developing products and processes in support of public policy that require highly innovative solutions to complex problems, another strong area for small firms. As an example, the trend in the development of DoD weapons technology gravitates toward increasingly sophisticated

prototype systems to counter future, unspecified threats rather than increased production of current systems (28:148-149). Again, the research supports small firm advantages in pursuing new technology development. According to the research above, small, innovative, labor-intensive firms such as those engaged in SBIR contracts would best utilize transferred technology from government laboratories. Mutual benefit results when the government receives a more innovative product for its contribution to the partnership and the small private firm is rewarded for its efforts through commercial spin-offs from the government technology. This evidence strongly argues for new research to determine if the advantages small firms demonstrate in private innovation continue under federal technology transfer activities.

Transfer Mechanisms

DoD R&D efforts currently take two primary forms: (1) contracted research funded by the DoD but carried out by contractors at their facilities, and (2) in-house research performed by government or contract scientists in federal facilities. Standard government contracts for R&D severely limits the technology transfer process. Technology transfer under these mechanisms occurs primarily through the definition of intellectual property rights in the contract.

While the government funds the contract to meet its requirement, technological benefits may accrue to the contractor directly through the nature of the contract requirement or indirectly via contract performance. Direct benefits rarely occur unless the contractor retains sole title to technology developed under the contract. Standard contract clauses required by law limit the contractor's ability to patent or otherwise protect technology developed under contract. The inability to capture market share during the initial commercialization of the technology poses too much risk for most government contractors. More often, technology developed under government contract

leaks into other contractor projects and is protected separately from the government work (4:52). Indirect benefits result when contractor personnel gain experience under a government contract that can then be applied towards the development of technology with commercial applications. Government acquisition personnel generally do not consider transfer possibilities when negotiating contracts for R&D or development. While the contract is probably the most widely employed mechanism that results in technology transfer from the government to the private sector, in most cases the resulting transfer is neither intended nor addressed.

In the last decade, increased interest in utilizing federal technology has generated several laws facilitating technology transfer to the private sector. In 1980, Congress passed the Stevenson-Wydler Act that made technology transfer a mission for all federal laboratories. The Bayh-Dole Act of 1980, later expanded by executive order in 1983, gave federal laboratories (including DoD labs) authority to grant private firms exclusive licenses to patents resulting from government funded projects. The Small Business Innovation Development Act (1982) created the Small Business Innovation Research program to stimulate commercial technological innovation among small private sector businesses. In 1986, the Federal Technology Transfer Act granted federal laboratories authority to enter into cooperative R&D agreements with commercial partners to pursue mutually beneficial research. More important, the Act gave laboratories the authority to negotiate licensing agreements with private firms for federally developed technology (5). These laws resulted in two important contractual instruments that allow the DoD to pursue R&D to meet its goals and missions, while allowing for technology transfer to the private sector.

First, the Cooperative Research and Development Agreement (CRDA), originally authorized by the Federal Technology Transfer Act of 1986, is an agreement between one or more federal agencies and one or more non-federal parties to pursue common R&D

interests. Negotiated between the federal laboratory and private parties, the CRDA does not fall under the Federal Acquisition Regulation, thereby freeing intellectual property rights from restrictive government regulations. Agreements potentially involve private sector access to government employees, equipment, facilities, services, or intellectual property, but not direct federal funding. On the other hand, the private party can provide similar resources as well as directly fund the project. The CRDA process provides incredible flexibility to the government and private industry to tailor each agreement to the unique properties of the technology in question within the governing law and regulations.

Private parties retain ownership to inventions developed by their employees and can negotiate licenses for inventions made by federal employees. However, the government retains royalty free right, for government purposes, to use all inventions made under a CRDA. This provision ensures that technology transfer occurs for the purpose of commercialization rather than for future resale back to the DoD (5).

The second technology transfer mechanism, the Small Business Innovative Research (SBIR) contract, differs significantly from the CRDA process. To begin, the program is devoted exclusively to small business (typically defined as 500 employees or less) and falls under the auspices of the Federal Acquisition Regulation. The nature of the contract vehicle allows for direct funding from the government to the private firm while allowing limited access to federal laboratory resources.

The Small Business Innovation Development Act requires that the DoD, along with other government agencies, set aside a portion of their R&D budgets for SBIR contracts. Each year the DoD identifies for small businesses SBIR research topics that contribute to its missions. Interested small businesses respond to these solicitations with a proposal describing how it will approach one of the identified research topics. Laboratory experts in the identified research areas review the proposals and award contracts to those chosen.

The SBIR program is composed of three phases with the most viable small business proposals competing at each phase to advance for further commercial development. Phase I contracts, valued up to $100,000, address a topic area identified in the DoD solicitation. Besides conducting research to provide to the DoD under the contract, Phase I SBIRs determine the technological feasibility of the research area for product or process development. Award of Phase II contracts, valued up to $750,000, depends upon the results of Phase I, the project's scientific and technical merit, and the project's potential for commercial applications. Phase III SBIR projects team the SBIR contractor with private sector, DoD or other federal agency partners to commercialize the Phase II result. To aid this development, further government R&D in the particular technology area is contracted with the original SBIR contractor (11).

In addition to firm size, AF decision-makers must choose the type of transfer mechanism as embodied by the agreement between federal and private parties in technology transfer. Some research in this area focuses on the type of contact occurring between federal laboratories and private firms. Contact is generally classified as occurring through advisory groups, collaboration with cost sharing (CWCS), collaboration without cost sharing (CNCS), personnel exchanges, licensing/spin-offs, active dissemination of information, and passive dissemination of information (39:57). This research effort focuses on comparing the results of technology transfer under CWCS contact and under CNCS contact. Cost sharing in this sense refers to the availability of resources for the private firms' research and development efforts on innovations resulting from technology transfer.

This thesis effort explores the CRDA as the method of collaboration with cost sharing. Originally authorized under the Federal Technology Transfer Act of 1986, CRDAs have several important properties that differentiate them from CNCS transfer mechanisms. First, the CRDA manifests an agreement between a federal laboratory and

another party to share resources to conduct research and development efforts within the laboratory agency's mission boundaries. Most important, the government partner provides diverse resources such as personnel, facilities, equipment or information to the research effort, but it cannot provide direct funding to the non-federal parties. The agreement spells out the resources each party brings to the research effort and the disbursal of intellectual property rights developed under the effort. Secondly, the CRDA, an untraditional procurement contract, bypasses Federal Acquisition Regulation guidelines. As such, this more flexible instrument allows laboratory officials considerable leeway in developing individual sharing arrangements depending on research needs. It is important to note the distinguishing CWCS features of resource sharing and flexibility without the transfer of funds (CRDA).

Some research supports the use of cost sharing with collaboration (CRDA) over the use of non-cost sharing without collaboration (SBIR) as a better method of transferring technology. One researcher offers that the potential losses to the private firm as a result of the cost sharing agreement influences the private collaborator to more critically evaluate the risks of entering into the CRDA. This, in turn, results in a higher rate of successful technology transfers for CWCS over other transfer mechanisms (39:59). Another explanation may be that the nature of the interaction between government and private industry personnel better facilitates the exchange of information resulting in a higher quality transfer of technology. Both parties have a vested interest in the successful exchange of information. The private party recipient may be more open to technological opportunities offered by the government side. Another researcher classifies this as a technology-push mechanism that, while resulting in fewer successes, pays bigger dividends in sales, earnings, and job creation over CNCS mechanisms (31:29).

A shortcoming of the CRDA lies in the resource gap between the basic R&D supported by the agreement with the federal laboratory and the funding and resources

needed to bring the transferred technology to commercial fruition (12:23). Government R&D support generally covers only 10% of the private firm's total cost to develop and market a new product resulting from technology transfer (39:59).

In contrast to the CRDA, this thesis explores the Small Business Innovation Research (SBIR) contract as the method of collaboration without cost sharing. Formal contractual agreements provide initial funding, designated Phase 1 funding, of research to qualified small businesses under the SBIR program in return for a definite end-product. The government provides follow-on funding, Phase 2 funding, for projects showing commercial promise. Final funding for commercialization can come from the private sector or from the federal agency responsible for the SBIR contract.

The fully funded R&D for Phases 1 and 2 stands out as an obvious advantage of the SBIR program. Additionally, the directed research leads to a definable conclusion specified by the contractual agreement. Research suggests that a great advantage of the SBIR program lies in the fact that a firm's proposal must go through an evaluation process by government technology experts before acceptance for later SBIR phases. The government rejects infeasible or poor proposals before substantial time or resources are applied by the firm in commercial development (31:30).

A roundtable discussion, including some small business executives and moderated by Department of Commerce and Department of Treasury officials, identified three flaws with the SBIR program. First, the application process is too lengthy for the small amount of funds received under the SBIR contracts. Second, government agencies tend to focus on mission-related proposals rather than those necessarily offering the greatest commercial potential. Third, a gap exists between public funding of initial R&D under the SBIR program and the larger amount of funds required to fully commercialize a transferred technology (12:23).

Prior Innovation Experience

Another factor examined by this research for an effect on innovative output is the firm's prior innovative experience. Prior innovative experience is defined as the cumulative experience the firm possesses for obtaining technology originating outside the firm, applying the technology to a particular firm problem, and developing a product or process from the new technology. While no prior research explores this factor, the basic argument for its inclusion in this study is supported by learning curve theory. The process of seeking out innovation opportunities, competing for limited funding (in the case of government R&D funds), negotiating agreements, performing research and development work, obtaining commercialization capital, and eventually marketing and selling a product or process requires vast effort and experience beyond the simple combination of an existing technology with a new opportunity. Parts of the process such as drafting a contract are very standardized and lend themselves well to repetitive learning, while other parts such as researching a technology area or developing a product for market are very individualized efforts that require unique tailoring for each new situation.

The repetitive part of the process involving contract competition, contracting, and administrative performance, while certainly not frivolous in nature, are very uniform, governed by extensive legal and regulatory guidance. This is especially true for contracts with the federal government such as SBIRs that are governed by the Federal Acquisition Regulation (FAR). The relative newness of CRDAs means less regulation, but the involvement of public funds interacting with the private sector inevitably draws increased scrutiny and control. These uniform processes lend themselves to learning curve theory.

Learning curve theory states that as workers become more experienced with a process, or as the process is improved over time, the number of hours required to produce an additional unit to output declines. Following on this idea, experience curves model the

effect of accumulated experience with the production of a product on the overall cost or price (25:30-35).

In the context of the commercial innovation of government technology the process of seeking out opportunities, contracting with the government for their use, teaming with outside partners for the technologies development, and marketing the resulting product or process certainly lend themselves to learning across multiple occurrences. More experienced firms in these learning opportunity areas move quicker to develop a technology at lower costs than do less experienced firms. Lower costs and swifter time to market enhances the possibility of commercializing a particular technology.

Balanced against these learning opportunity areas are the more random forces of the market that cannot be predicted regardless of experience. For instance, no matter the commercial promise of a government-owned technology, the lack of consumer demand due to the development of other technologies or a change in preference cannot be overcome by learning. Additionally, factors on the production side such as a lack of funding or government performance problems also inhibit the commercialization of a technology, regardless of the firm's accumulated experiences.

Prior Technology Experience

The fourth factor examined by this research for an effect on a firm's ability of commercially innovate is the firm's prior experience in the technology area to which the innovation is applied. For instance, a firm may have many years of experience manufacturing automobile engines from steel when an innovative opportunity presents itself that would allow the firm to manufacture the engine block from a ceramic material at a lesser cost while substantially improving engine performance. This research asks if the engine producer's prior manufacturing experience contributes to its ability to develop a new product composed of the ceramic material.

The application of experience curves is relevant to this research question as well. Nahmias states that such curves are particularly appropriate in industries undergoing major technological changes such as the microelectronics industry and offers that the decline in the price of integrated circuits over time as an example of this phenomenon (25:30-35). As a firm gains experience in a technology area, it is better able to control costs associated with the production of items resulting from that technology. For instance, for the years during which the engine producer manufactured engine blocks from steel, the firm accumulated knowledge of materials and processes that can be applied to manufacturing engines from the new material. A firm new to this technology area starts at the top of the experience curve. Outside assistance changes the slope of the curve, hastening learning, but many learning events need be experienced by the new firm to bring its costs down to the level of the experienced firm. Quoting Dosing, "Innovative activities present - to different degrees - firm-specific, local, and cumulative features." (21:113).

A distinction must be made here between: (1) the learning that occurs during the innovation process regarding the new technology which must be transformed into an output by the acquiring firm; and, (2) the learning the acquiring firm has accumulated for its area of technological expertise to which the innovation is applied. For the purpose of this study, every firm included is assumed to be at the top of the experience curve for the innovative technology. In contrast, firms possess varying degrees of technological mastery in their primary areas of production that allows them to both improve their production process and incorporate enhancements from other technology areas (21:147-149).

Maturity of Technology

The fifth and final factor examined in this study for its effect on a firm's commercial innovation ability is the maturity of the technology borrowed from another market for use in developing a new product or process. The illustration below presents Malecki's simple linear model of technological change illustrating the stages of technology before it finds it way into a final marketed product (21:114-123).

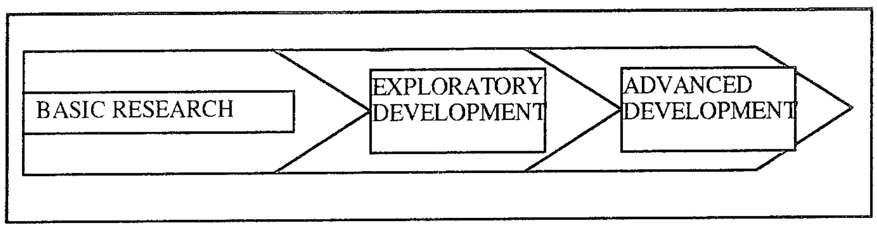

FIGURE 4 Malecki's Simple Linear Model of Technology Change

While this model does not capture all of the feedbacks and interactions present in the innovation process, it provides the basic stages through which a technology develops along a vector toward a specific product or process. For the purpose of this study, it is the acquiring firm's perception of the state of the technology which potentially influences its incorporation in a commercial product. For example, a firm may acquire the right to use the technology embodied in another firm's final product. However, to be useful to the new firm, the technology must be returned to the laboratory to be adapted for its new use. The fact that the licensing firm perceived the technology as fully developed is irrelevant to the acquiring firm's technological and commercial innovation.

For the innovating firm, the more mature the technology, the greater the innovation potential at the point of the transfer. In turn, greater innovation potential translates into a greater likelihood of commercialization and a shorter time to market. Basic research conducted primarily at universities and government laboratories does not

demonstrate a strong link to commercial development. Firms generally become heavily involved at the applied research stage when potential products are envisioned, but considerable development is still required. Product development focuses on production design and engineering of a final product with a potential market established (21:117-119). Malecki's model does not include a final product stage, but after examining current Air Force CRDAs, this researcher includes this stage as the point where an acquiring firm receives fully developed technology embodied in a product which it in turns markets to other users without further modification.

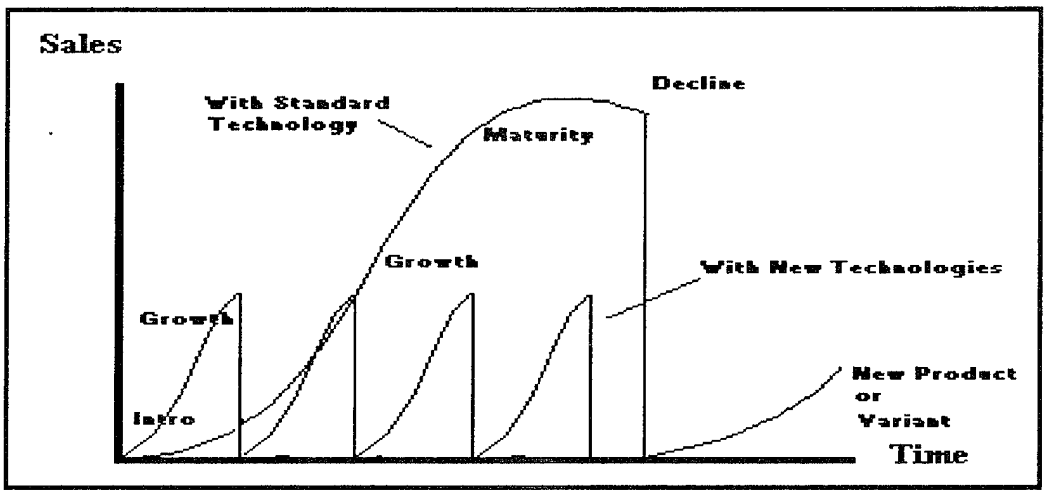

FIGURE 5 Meredith's Effect of Increasing Technological Change on Product Life Cycles

The graph above presents Meredith's original illustration of the effect of increasing technological innovation on product life cycles. The original product life cycle graph illustrates the change in sales volume for a product over time beginning at a point of zero sales and ultimately ending at zero sales. In between, the product matures through phases from innovation, growth of sales, maturity of the market, and ultimately decline as new innovations usurp market share. Increasingly rapid technological innovation shortens the life cycle of products in the marketplace. In order to capture market share, firms must

introduce new products into the marketplace quickly. Meredith argues that smaller firms are better positioned to quickly bring new products to market because of less bureaucracy (23:253).

The graph below modifies Meredith's original illustration of technology's affect on product life cycles to better illustrate the importance of the maturity of the transferred technology. The graph below uses cash flows associated with a product rather than sales to allow for a negative cash flow during part of the product's life cycle. The shortcoming of previous product life cycle graphs is that they fail to recognize the significant period of research and development that occurs prior to the introduction of the product.

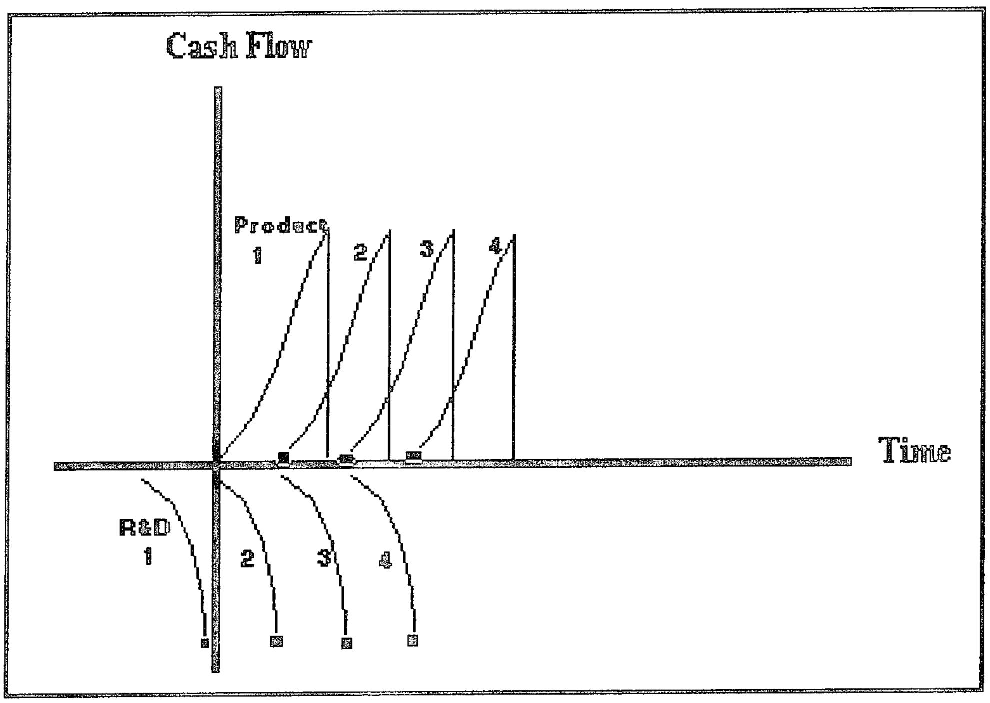

FIGURE 6 Modification of Meredith's Effect of Increasing Technological Change on Product Life Cycles to Capture Cash Flows

The position of these events in time prior to introducing the product to the market determines not only when the product or process emerges, but also ultimately its success. Innovation resulting from the transfer of immature technology requires a greater development period that ultimately affects the resulting product's position in the market. The longer time to market shortens the product's life cycle in the face of newer technologies.

Moreover, Markusen suggests an industry profit cycle model analogous with the product life cycle demonstrating the affect of the maturity of technology and its position along its life cycle on an industry's profits. Adapting this model for the single firm emphasizes the importance of the maturity of technology to the firm's market position and ultimately its profit.

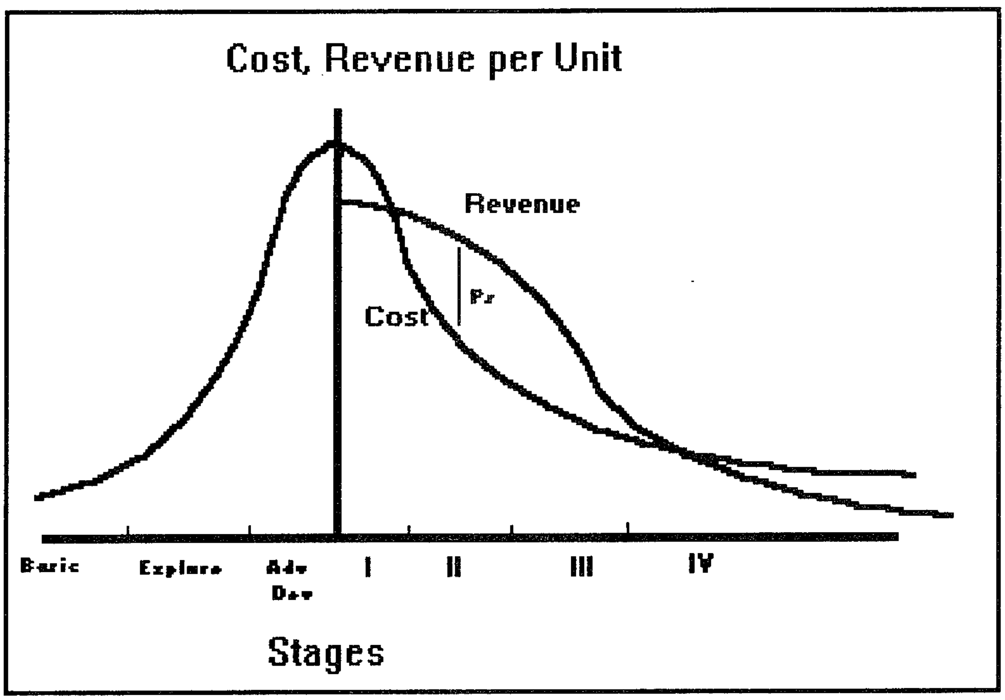

FIGURE 7 Markusen's Industry Profit Cycle with Super Profit Stage

First, the maturity of the technology transferred affects the cost area a firm experiences prior to introducing the product for sale. The more mature the technology, the greater the firm's potential return on its investment and therefore, the more likely the firm will commercialize the technology. Additionally, when multiple competing technologies are introduced, a longer time to market means the firm will not achieve Markusen's super profit stage that would result from a monopoly position in the market. The firm enjoys a super profit stage in its product's development when the product has been introduced commercially and captures a significant market share due to its unique qualities. This monopolistic environment is discussed by Schumpeter as being an optimal condition for innovation. Firms participating in innovative activities benefit from more mature technologies because innovation increases their opportunity to experience the super profit market stage (21).

Measuring Innovation

An important consideration when examining the innovation process involves choosing a proper measure to gauge the success of the technology transfer. Most of the existing measures focus on objective standards of success for the private firm resulting from the innovation process, such as measures of return on investment or measures of intellectual property rights. Of these objective measures, some concentrate on a technology recipient's success such as changes in the user's revenues and costs (18), the number of jobs created (27), the number of products launched (8;19), the financial commitments the users has received (36), or the user's market share (24;38). Other measures attempt to capture the benefit of the transferred technology outside the firm such as the number of patents filed (16;37) or the degree of technology adoption (10).

Considered individually, these diverse measures exhibit several flaws. For instance, some information such as revenues, costs, or outside financial commitments

related to specific technologies are generally considered sensitive information that private firms are unwilling to divulge. The sensitive nature of this data makes collecting difficult and possibly unreliable due to misreporting. In other cases, measures do not accurately reflect the value of the transferred technology. For instance, it is difficult to determine the causality for hiring new personnel. Directly attributing the hiring to the results of technology transfer may overstate the significance of the transfer event. Similar causality problems occur when measuring the number of user requests or the number of products launched. Specific evidence shows that the number of patents does not accurately reflect the value of an innovation since many patented ideas are never used (37:172) and not all innovation is patented (1:568). One researcher attempts to overcome this problem by weighting the patents by the number of citations for the original patent in documentation for later innovations (37). However, applying this method to a broad latitudinal study involving many diverse technologies makes data collection very time consuming. Finally, input measures, such as cost of R&D conducted, do not directly measure the value of the R&D results (1:567).

In contrast to the previous measures, Dr. Robert E. Berger and others performed specific research that attempted to capture the totality of the commercialization decision. Their study examined the degree of commercialization for over 800 SBIR program participants by classifying the data, gathered from telephone interviews, into five general categories. The five levels of commercialization are identified as:

> Level 1 - Commercialization has occurred. The SBIR awardee has produced and delivered for sale a product or service developed as a result of the SBIR effort. A level-one company must be in a production mode; the sale of only one or two products for testing purposes would not qualify for this category. The sales could be in either the public or private sectors.

Level 2 - Something has happened. The SBIR awardee has achieved an intermediate goal demonstrating clear movement toward commercialization of the product or service. This includes such major events as acquisitions, outside financial commitments, or the formation of a spin-off company indicating that "something has happened" to foster the prospects of commercialization.

Level 3 - Actively seeking commercialization. The company is actively pursuing options that would enable it to commercialize the product or service, but presently there are no substantive outcomes.

Level 4 - Interested in its commercialization. The company believes that its SBIR-developed technology has sales potential but it is not currently taking action toward this end. This category also applies to companies pursuing further R&D that could lead to future product sales (i.e., it is premature to actively pursue commercialization).

Level 5 - Commercialization not expected. The SBIR project is not now and unlikely ever to be commercialized. This could mean that the SBIR project was never amenable to the development of a product or service. (6)

To ensure accuracy, the interviewers challenged participants' responses to temper any inflation of commercial success. By subjectively classifying the degree of commercialization according to the levels given above, the researchers obtained a continuous variable. They examined the relationship between the degree of commercialization to other variables gathered from their interviews through analyses of variance for categorical variables or a Pearson correlation coefficient for ordinal or continuous variables. As the commercialization of transferred technology takes considerable time, the useful data collected by Dr. Berger resulted from technology transfers occurring on average, four years prior to the study (6;7).

Conclusion

Dr. Berger's study provides a timely method for the collection of relevant data measuring the innovative ability of firms. The previous study confined itself to the examination of factors affecting small firms under SBIR contracts. However, the same method can be applied to this examination of factors affecting small and large firms under both CRDAs and SBIRs.

His work develops a method very pertinent to the goal of this study. A primary purpose under the law for the creation of SBIRs and CRDAs is the stimulation of the economy by transferring government technology to the private sector. As presented previously, technology spurs the economy through the creation of new products for consumption, through new processes that free resources for other uses, and through the stimulation of investment in the capital goods employed for the production of new products and processes. Commercialization of innovative technology is the sum total expression of this process. The stage of commercialization of a particular product or process represents the firm's commitment to obtaining the elements of production and the consumers valuation of the resulting product. The stage of commercialization measures how well a given technology transfer event meets the goal of the law creating the innovation opportunity.

Evidence exists supporting the significant effects of this study's variables for the firm when attempting to commercialize innovative technology. The next chapter explains how these variables are employed to examine commercialization when the Air Force is involved in the innovation process.

III. Methodology

Overview

This chapter describes the approach used to test the hypotheses presented in the introduction. Additionally this chapter describes the sample population from which data were collected, the method of data collection, and the statistical methods used to analyze the data.

Approach

Air Force Material Command (AFMC) manages the technology transfer from the USAF to any outside parties, including private firms. The AFMC Technology Transfer handbook states the purpose of USAF technology transfer as, "Transferring Air Force-developed technology with potential commercial applications is part of the AFMC mission" (3). With this statement, the Command formalizes an on-going goal of making Air Force-developed technology available to private firms to incorporate into their products for commercial use. Moreover, a principal objective of the SBIR program is to increase the commercialization of technology developed through SBIR research and development (11). A significant criterion of success for a private firm on the receiving end of the technology transfer is the commercialization of the technology in an end product or products.

By measuring the degree of commercialization of products or processes resulting from Air Force-developed or financed technology, one can determine the significance of transfer process related factors such as the conditions of the transfer agreement, the size of the firm, or the maturity of the technology involved.

As mentioned previously, Dr. Robert E. Berger's research attempts to capture the influence of the small firm's attributes such as the number of employees, its market

orientation, or the existence of a marketing plan on the commercialization of its product developed initially under government contract. This thesis replicates the form of Dr. Berger's study using data from firms having innovation agreements (CRDAs or SBIRs) with the Air Force. It also extends the study to include traditionally large businesses under CRDAs as well as small businesses engaged in CRDAs and SBIRs.

Instrument

The primary purpose of this thesis is to test the hypotheses given in Chapter One and investigate the causal effects of firm attributes on the degree of commercialization of transferred technology. A combination of structured and unstructured questions provides a means of collecting data necessary for testing the significance of the relationships between the independent variables and the dependent variable, the degree of commercialization, and to establish evidence of causality.

A secondary objective for the data gathered from firms engaging in CRDAs and SBIRs is to describe the relatively new, expanding field of firms involved in the technology transfer process with the Air Force. An interview with Mr. Steve Guilfoos, AFMC TTO, reveals that there has not been a descriptive study of the population of CRDA participants and their perceptions of factors influencing technology transfer outcomes (15). Consequently, the design of the survey instrument found in Appendix A also strives to encourage firm contacts to share their views of factors affecting the technology transfer process.

Section I of the survey collects basic information needed to track respondents and follow up as needed. Section II provides several unstructured questions to capture continuous and nominal data reflecting independent firm attributes to support hypotheses regarding causal relationships with the degree of commercialization. The design of Section III allows the researcher to classify the degree of commercialization of any products

resulting from the technology transfer process. While the questions are unstructured, the section as a whole acts as a filter to challenge respondents' reporting of commercialization activities. Dr. Berger's previous study found a natural tendency in the respondents to inflate their commercialization success (6). The data resulting from Sections II & III allow the researcher to conduct the tests of hypotheses stated in the Chapter One. Section IV captures descriptive information about the CRDA firms and the outcomes of the technology transfer process requested by AFMC TTO. Additionally, it provides the respondent with the opportunity to expand on previous answers and comment on its technology transfer experience in a free-form manner. In discussions with Craig J. Little, the project manager for the Dr. Berger's initial study, it was noted that SBIR program participants, as a whole, are very eager to discuss the results of their projects (20).

Dr. Berger's study used a telephone survey to conduct interviews with over 800 SBIR contractors (6). The draft survey in Appendix A follows substantially the survey employed in Dr. Berger's study. The extensive use of the original survey serves as a substantial pretest for the one employed in this thesis. A conversation with Mr. Little confirms that the survey has been modified since Dr. Berger's original work to improve participant responses (20).

Section II has been expanded beyond the original survey to collect additional factors that may have a causal relationship to the commercialization of transferred technology. The interview questions were reviewed by members of the AFMC TTO office to refine the questions for CRDA respondents.

Dr. Berger's study involved interviewing SBIR program participants to determine the degree of commercialization of their products initially developed under contract with various government agencies. This research employs interviews conducted with SBIR and CRDA program participants to determine the degree of commercialization of any products or processes developed under the SBIRs or CRDAs with the Air Force during fiscal years

1991 through 1993 in the electrotechnology area. The time frame for this study results from the fact that FY 1991 is the first year in which the Air Force had significant numbers of CRDAs. Additionally, three years of CRDAs were observed to balance the need for statistically significant numbers of CRDAs with the recognition that a time lag exists between the initial transfer event and the development of any product resulting from it. While the time lag is not at least four years for all of the CRDAs as Dr. Berger found typical for product commercialization in his study, it is considered sufficient for some action to occur under each agreement so that legitimate differentiation in commercialization could be observed for individual CRDAs and SBIRs. This study employs a single technology area, electrotechnology, to limit the population of CRDAs and SBIRs in order to limit the possible influence of different markets on the commercialization resulting from the SBIRs and CRDAs.

Dr. Berger's study analyzed the results of the interviews to classify the degree of commercialization of the firm's product into one of five categories. This thesis applies the same classification scheme to similar interview data collected from Air Force SBIR and CRDA participants. The commercialization categories and associated definitions almost duplicate exactly those employed by Dr. Berger and set out in Chapter Two. The commercialization ratings applied to the data collected for this thesis are:

> Level 1 - Commercialization has occurred. The SBIR or CRDA awardee has produced and delivered for sale a product or service developed as a result of the transfer agreement with the Air Force. A level-one company must be in a production mode; the sale of only one or two products for testing purposes would not qualify for this category. The sales could be in either the public or private sectors.

> Level 2 - Something has happened. The SBIR or CRDA awardee has achieved an intermediate goal demonstrating clear movement toward commercialization of the product or service. This includes such major events as acquisitions, outside financial commitments,

or the formation of a spin-off company indicating that "something has happened" to foster the prospects of commercialization.

Level 3 - Actively seeking commercialization. The company is actively pursuing options that would enable it to commercialize the product or service, but presently there are no substantive outcomes.

Level 4 - Interested in its commercialization. The company believes that its Air Force-derived technology has sales potential but it is not currently taking action toward this end. This category also applies to companies pursuing further R&D that could lead to future product sales (i.e., it is premature to actively pursue commercialization).

Level 5 - Commercialization not expected. The Air Force-derived technology is not now, and unlikely ever to be, commercialized.

Telephone interviews were conducted with both SBIR and CRDA recipients using the survey instrument attached as Appendix A. Section III of the survey instrument in Appendix A contains the questions to used to determine the degree of commercialization of the sampled firms' products. This classification is considered the dependent variable, while various firm attributes collected via Section II of the survey instrument are considered as independent factors that can affect the degree of commercialization.

As in Dr. Berger's work, the survey used in this research collects data regarding various attributes of the firms engaged in the technology innovation agreements with the US Air Force. The purpose for collecting this data is to test the relationship between the five factors (firm size, agreement type, innovation experience, technology experience, and maturity of technology) with the commercialization of Air Force technology by private firms.

Section I of the telephone survey interview guide records general firm information for each of the SBIR and CRDA partners interviewed for this study. Section II of the guide collects data related to the independent variables to be tested for significance in

supporting this research's hypotheses. The table below relates the numbered questions in the survey guide to the research hypotheses.

TABLE 1 Relationships Between Independent Variables and Survey Questions

INDEPENDENT VARIABLE	TYPE OF MEASURE	MEASURE / SURVEY QUESTION
A. FIRM SIZE	1. ABSOLUTE MEASURE	(1) NUMBER OF EMPLOYEES (B1)
		(2) NUMBER OF DEDICATED EMPLOYEES UNDER MECHANISM (B3)
		(3) NUMBER OF ADVANCED DEGREES EMPLOYED UNDER MECHANISM (F2)
		(4) PERCENTAGE OF FIRM RESOURCES APPLIED TO R&D * NUMBER OF EMPLOYEES (A2 * B1)
	2. RELATIVE MEASURE	(1) PERCENTAGE OF EMPLOYEES DEDICATED (B3/B1)
		(2) PERCENTAGE OF FIRM RESOURCES APPLIED TO R&D (A2)
		(3) MARKET SHARE (D2)
B. PRIOR INNOVATION EXPERIENCE		(1) NUMBER OF PRIOR INNOVATION AGREEMENTS WITH THE FEDERAL GOVT (E1)
		(2) TOTAL NUMBER OF PRIOR INNOVATION AGREEMENTS (GOVT/EDUCATIONAL/PRIVATE) (E1+E2+E3)

C. PRIOR TECHNOLOGY AREA EXPERIENCE		(1) NUMBER OF YEARS IN TECHNOLOGY AREA (F1)
		(2) BUSINESS ORIENTATION (B2)
D. MATURITY OF TECHNOLOGY		(1) MATURITY OF TECHNOLOGY (G1)
E. CONTRACT MECHANISM		(1) CONTRACT MECHANISM

In order to test the hypotheses, this study's methodology first conducts a paired t-test to determine if there is a significant difference between the two innovation mechanisms. As a result of the t-test indicating that a significant difference exists between the two mechanisms, the methodology treats each as originating from a different population for the purpose of conducting linear regression. Next, the degree of commercialization for each sample based on its innovation mechanism is regressed against the four remaining factors: Firm size, innovation experience, technology experience, and maturity of technology to determine the significance and direction of the independent variables. This researcher conducted several different regressions substituting the different measures proposed for each independent variable.

First, an absolute measure of firm size, the total number of firm employees, is regressed against the degree of innovation. This measure allows for the testing of Schumpeter's original argument that absolute size, implying greater resources, produces an environment more conducive to innovation. In contrast, small firm advocates point out that competitive forces based on market share incentivizes larger firms to suppress innovation in order to preserve existing markets for current products.

A relative measures of firm size, the firm's market share, is regressed against the degree of commercial innovation. This measure focuses on the firm's commercialization efforts relative to its position in the market.

Three measures of prior innovation experience are regressed against the degree of commercial innovation. The first, the number of prior government innovation agreements, examines learning related strictly to government innovation processes such as proposing, negotiating, and performing under government agreements. The second measure, the number of prior private innovation agreements (to include educational and private firm teaming), explores learning related to the more broad concept of teaming. In both cases, if learning is a significant factor, the degree of commercialization is expected to increase with an increase in the number of prior agreements. The third measure, the percentage of the firm's total sales to the private sector at the time of the innovation agreement intends to capture the experience the firm possesses in dealing with the commercialization of products. Again, if learning is a factor in commercialization, the greater a firm's experience (as represented by its current sales to the private sector), the greater the degree of commercialization.

One measure of the firm's experience in the technology area, the number of years experience in the technology area to which the innovation is applied, is regressed against the degree of commercialization. This variable examines the relevance of experience curves for the firm's technology area to influence the commercialization of innovations resulting from that technology area.

One measure of the maturity of technology, the firm's assessment of the state of the technology received via the innovation agreement as applicable to the receiving firm's intended use for developing a product or process, is regressed against the degree of commercial innovation. According to the modification of Meredith's product life cycle curve, the more mature the technology for the receiving firm, the greater the degree of commercialization.

This study seeks to support causal relationships via three types of evidence. First, the covariations of the independent variables and the dependent variable are examined.

For example, does the degree of commercialization of a product vary in a predictable manner as the number of employees in the development firm changes. Second, the independent attributes are chosen to preserve the chronological order of events in the technology transfer process. The resulting commercialization occurs after various attributes such as firm size, transfer mechanism, and market orientation are established. Lastly, while many other possible causes of commercialization exist, this study attempts to control them via a matching process whereby firms are grouped according to product type. With such grouping, this study expects to control many unquantifiable factors that are unique to a market or product, while allowing specific variables such as firm size or transfer mechanism to vary.

Sample

The populations for this study result from the databases of the Air Force Material Command Technology Transition Office and the AFMC Small Business Office for CRDAs and SBIRs, respectively. The information provided by both agencies consists of company addresses, telephone numbers and points-of-contact. Due to the geographically separated locations of the firms, data for each was collected via a telephone interview following the general outline of the survey guide in Appendix A. Due to the relatively small population of CRDAs and SBIRs during the relevant time period and the matching process used in this study to control extraneous influences, an intense effort was made to collect data from all firms in the population to increase the sample size.

The AFMC TTO Transfer Agreement Database provided a population of all Air Force CRDAs between FY91 - FY95. Considering the four year time lag cited in previous research for the commercial development of transferred technology only the fiscal years 1991-1993 are examined in this study(6;7). A population of ninety-two CRDAs exist for these fiscal years. After sorting the data by product type, this researcher found 39 firms

engaged in CRDAs to develop electrotechnology products or processes related to electrical components. Thirteen CRDAs existed for computer products or processes, nine for biomedical products, seven for materials development, seven for aeronautical applications, seven for manufacturing technology, four for communications technology, four for environmental products or processes, two for chemistry and one for physics.

Due to the population size, the electrotechnology area was chosen for this study. Of the 39 firms, two were rejected because the agreement involved an educational institution rather than a private firm. This researcher attempted contact with all 37 remaining firms and eventually contacted 32. Three firms declined to participate up front and six more failed to respond to initial and follow-up requests for interviews. All told, a 62% response rate was achieved for the population of electrotechnology CRDAs for fiscal years 1991-1993.

The second data source, the AFMC Small Business Innovative Research office, provided data on all Air Force Phase II SBIRs awarded during FY91-FY93. Twenty-six firms engaging in Phase II electrotechnology SBIRs were identified. Twenty three of the firms were contacted and four of these declined to participate. This researcher interviewed 19 SBIR contractors for a 73% response rate.

Analysis Method

To begin the analysis of the data, this study conducts a two-sample t statistic test to determine if a significant difference in the degree of commercialization exists between CRDAs and SBIRs. The null state for this test of hypothesis is that there is no difference between the degree of commercialization of products resulting from SBIR contracts than result from CRDAs with the USAF. The alternate hypothesis for this test proposes that a significant difference exists between the degree of commercialization of products resulting from SBIR contracts than resulting from CRDAs with the USAF. Currently, the direction

of this difference cannot be postulated. The purpose of this test is to support the hypothesis that significantly different outcomes result from the two agreement types due to the nature of the relationship between the government and the private partner under each. The SBIR directly funds specific research, while the CRDA allows for greater interaction between government and private technical resources. Moreover, the SBIR requirements process is screened and directed toward a definite outcome, while the CRDA process is not screened and outcomes are not formalized in a binding legal document.

The result of the t-test allows the two samples to be treated as originating from different populations. For each population, the remaining factors of firm size, innovation experience, technical experience, and the maturity of technology are regressed against the degree of commercialization to determine the significance and direction of each independent variable. These results allow the researcher to draw the conclusions presented in the next chapter.

In light of the many possible external and internal factor influences on the outcome of commercialization of a product developed from transferred technology, multiple regression analysis is used to screen potential independent variables. As stated in the Approach section of this chapter, this analysis treats the degree of commercialization as a qualitative variable with values of 1 - 5 corresponding to the degree of commercialization. The analysis uses the quantitative data gathered from the survey directly as independent variables or in the case of nominal data, uses dummy variables to represent different categories.

Limitations

The data used in this study is self-reported by the employees of the firms interviewed. While the construction of the interview permits fairly strict categorization of

the dependent variable, the degree of commercialization, the independent variables are accepted without verification.

While restricting data collection to one industry type, electrotechnology, attempts to eliminate industry-related biases toward commercial innovation, this author realizes that a vast spectrum of efforts span the electrotechnology industry so that market influences for one specific technology do not equal the market influences for another. These diverse influences result in large unexplained variations. However, they do not diminish the importance of identifying common influences identified and studied for the purpose of improving the innovation process.

Chapter Four describes the results of applying the methodology set out in this chapter to the data collected.

IV. Results

Data

The data used in this study resulted from interviews with project managers or company executives familiar with the project. The data is self-reported and not verified beyond ensuring that it is internally consistent within the context of the interview. However, on the whole, the participants spoke openly about their experiences working with the Air Force. In order to ensure frank and honest responses to the interviewer's questions, the respondents and their firms are assured of anonymity in this report. The candid responses received from the participants leads this researcher to conclude that the data gathered for the independent variables, firm size, market share, prior innovation experience, technology area experience and maturity of the technology, are true to the best knowledge of the respondent.

Just as important, the data gathered for use in generating the dependent variable resulted from a series of questions regarding the outcome of each SBIR contract or CRDA agreement. While proud employees, project members and owners want to paint the best picture of their company's work to outsiders, especially a member of one of their major customers, the nature of the questions allows this researcher to ensure uninflated data points. The questions ask about sales or business plans for future sales of any product or service resulting from the contract or agreement, what customers purchased the product or service, how is the firm financing the commercialization effort, etc. The complete set of questions used to generate the dependent variable values are in Section IV of the Sample Interview Guide located in Appendix A. The questions allow for the categorization of the result of each SBIR or CRDA at a given point in time within the five levels of commercialization defined in chapter three. Consequently, this researcher

believes that the resulting variable accurately represents the characteristic it is intended to measure.

The following sections examine the firms' responses for each of the five sample independent variables examined in this study. The data is further broken down and analyzed by transfer mechanism, either SBIR or CRDA. The complete data set is located in Appendix B. The significance of each variable is determined by multiple regression analysis and the results discussed. Finally, anecdotal evidence resulting from interviews with the sampled firms is presented.

Transfer Mechanism

This research first asks if there is a significant difference in the degree of commercialization when only the transfer mechanism, either SBIR or CRDA is considered. A paired t-test of the mean degree of commercialization reveals that the sample SBIR contracts achieved a significantly greater degree of commercialization than the sample CRDA agreements (see page one of Appendix C for the result of the paired t-test). As a result, this study treats the data from the firm interviews as coming from two different populations based on transfer mechanism. The charts below show the relative breakout of the degree of commercialization for each mechanism.

Moreover, a comparison of the resulting commercialization by transfer mechanism, reveals the natures of the two types of contracts. Examining the agreement type pie charts below showing degree of commercialization in relative percentages reveals that while the sample CRDAs achieve a greater percentage of fully commercialized technologies (17% v. 5%), the sample SBIRs achieve a far greater percentage of intermediate commercialization (79% v. 29%). Additionally, none of the sample SBIR contractors reported a level V commercialization result: that there is no chance of commercializing the technology.

However, 37% of the CRDA partners report no possibility of commercialization resulting from their commercial innovation process.

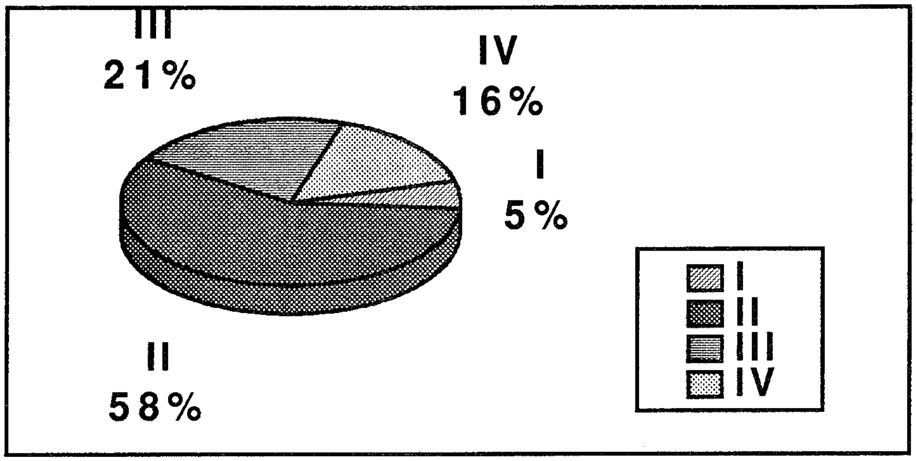

FIGURE 8 Degree of Commercialization - SBIR Contracts

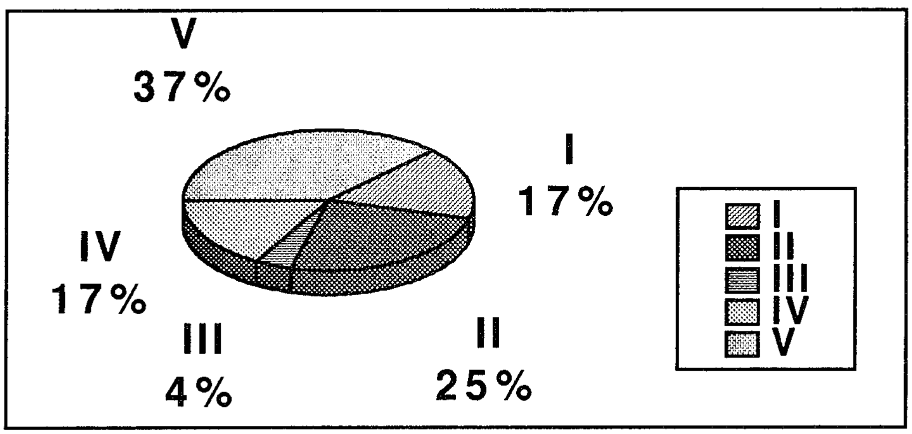

FIGURE 9 Degree of Commercialization - CRDA Agreements

The incentive structures of the two mechanisms drive this result. First, the SBIR process screens potential projects from Phase I to Phase II to ensure those selected promise stronger development possibilities. Moreover, the sample Phase II SBIR contracts generally call for a deliverable end-item for which the AF reimburses the contractor for development costs. This process ensures very few completed Phase II

SBIRs result in an end item with no commercialization potential (levels IV and V). Additionally, the Phase I and II funding moves the technology through the initial development stages toward commercialization (level II and III). However, the process breaks down when firms must make the final leap to commercialization (level I). The Department of Commerce roundtable identifies the process as the cause of the failure to commercialize. Government agencies fund SBIR projects to meet mission-related needs, but do not provide financial and other support necessary to fully commercialize a technology (10:23).

Other research reports that government R&D funding covers only 10% of the private firm's total cost to develop and market a new product (39:59). Anecdotal evidence gathered from interviews with the sample SBIR contractors generally supports this idea. Many of the sample contractors praised the SBIR process for orienting the company towards a deliverable end-item or prototype which leaves the firms with demonstrable technology. Almost all extol the technical support given by the government. Additionally, half of the sample contractors indicate their firms would not have pursued the project's technology area without government funding. Many of these respondents see commercial potential for their technologies, but either cannot obtain private funding or cannot justify the risk involved in raising development capital.

While the contractors generally praise the SBIR process for supporting innovation, few think the process supports the commercialization of their technology. One small semiconductor manufacturer labels Phase III SBIRs, touted as a mechanism for transitioning promising technologies to commercial products as, "mythical beasts" while another calls it, "a figment of the Air Force's imagination." All of the contractors note the existence of a financial gap between SBIR funding and full commercialization of their product, while some also assert that Air Force contract requirements lack the flexibility to ensure a commercial design.

The SBIR contractors possessing a level I or II degree of commercialization exhibit at least one of the following characteristics. One, the contractor indicates its firm intends to pursue development of a commercial end item similar to the SBIR requirement even without government funding. Two, the contractor states that government interest in the SBIR contract either as an end-item or as an element of a larger system generates interest in their product from large businesses. In other words, the SBIR requirement closely mirrors what the firms and/or their financial backers see as a viable commercial producťThe CRDA incentive structure places more risk on the private partner which must bring its own financial resources into any commercialization effort. As Winebrake notes, the risk to the private firm forces it to more critically evaluate the technology before expending resources on the transfer project (39). This explains the greater number of successful commercializations (level I), as well as the greater number of truly unsuccessful commercialization efforts (levels IV and V). Risk averse firms push projects toward full commercialization that offer relatively sure returns. They quickly abandon or put on the shelf projects that use their own funds that do not promise sufficient returns. In contrast, the SBIR contract funding mitigates some initial development risks to the company because the Air Force pays for the initial development, resulting in a greater number of level II and III commercialization results, but fewer fully commercialized projects.

Firm Size

This research examines two measures of firm size, the number of employees as a measure of absolute size and market share as a measure of relative size.

Number of Employees - SBIRs. The absolute size of the sample SBIR contractors as shown in the pie chart below spread evenly between very small firms with only a single employee-owner to a firm with 100 employees. Examining the commercialization result by firm size indicates little difference across SBIR contractor firm sizes. Moreover the result of multiple regression analysis (see Appendix C, page C-2) indicates that a significant relationship does not exist between the number of employees of the sampled firm and the degree of commercialization achieved for the sampled technology. This result contrasts dramatically with the CRDA result below. One should note that the limited range of firm sizes in the SBIR sample precludes the appearance of significant differences in the degree of commercialization. This is a problem with using the number of employees as an absolute size measure of SBIR contractors, which by definition must have less than 500 employees.

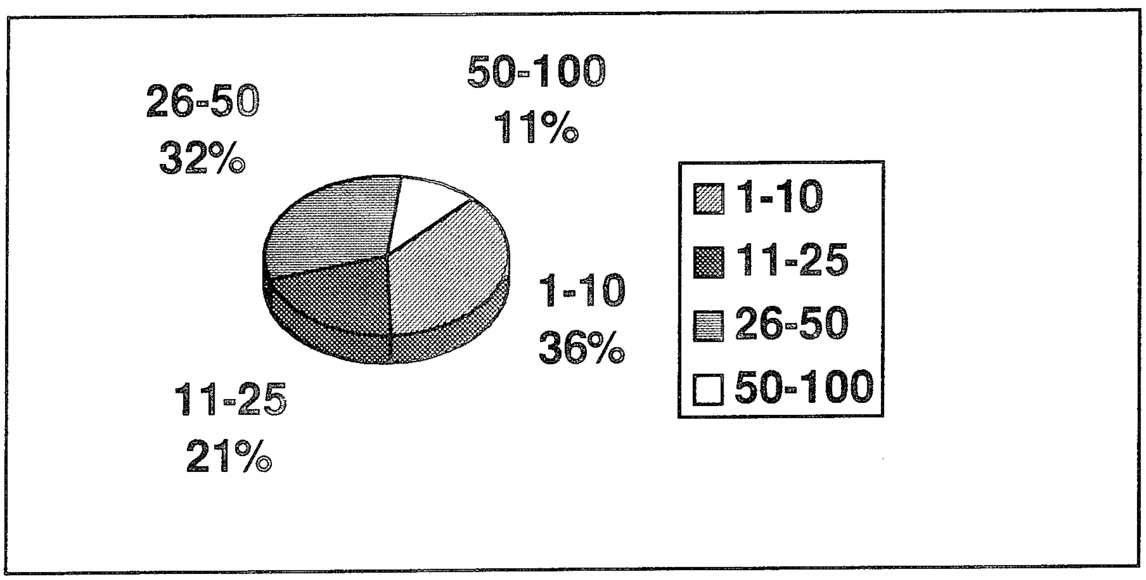

FIGURE 10 Number of Employees - SBIR Contracts

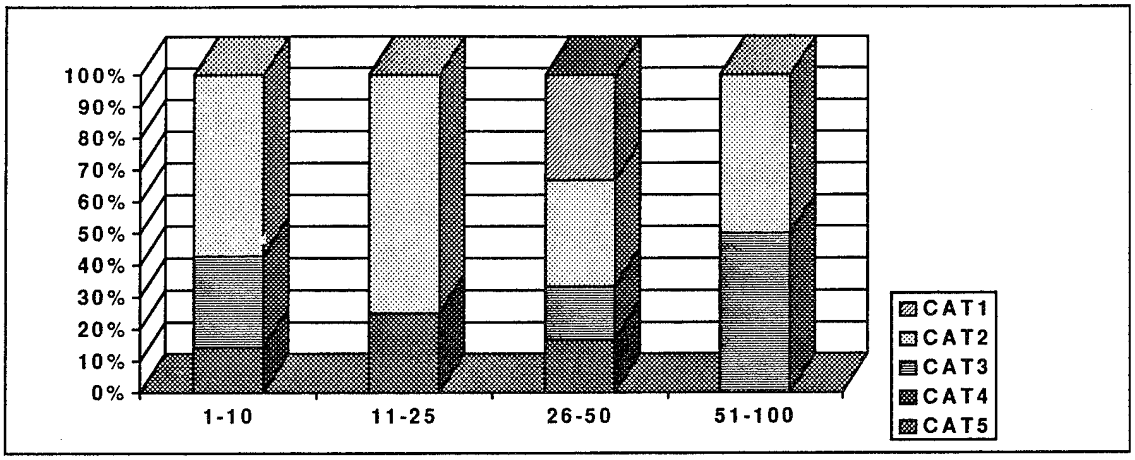

FIGURE 11 Degree of Commercialization by Size (Number of Employees) - SBIRs

Market Share - SBIRs. The relative measure of firm size, market share, offers little insight for SBIR contractors as well. In all but two cases, the firms did not possess a market share in the technology area that is the subject of their SBIR contract. Obviously, multiple regression analysis found no significant relationship between the SBIR contractor's market share and the degree of commercialization of their technology.

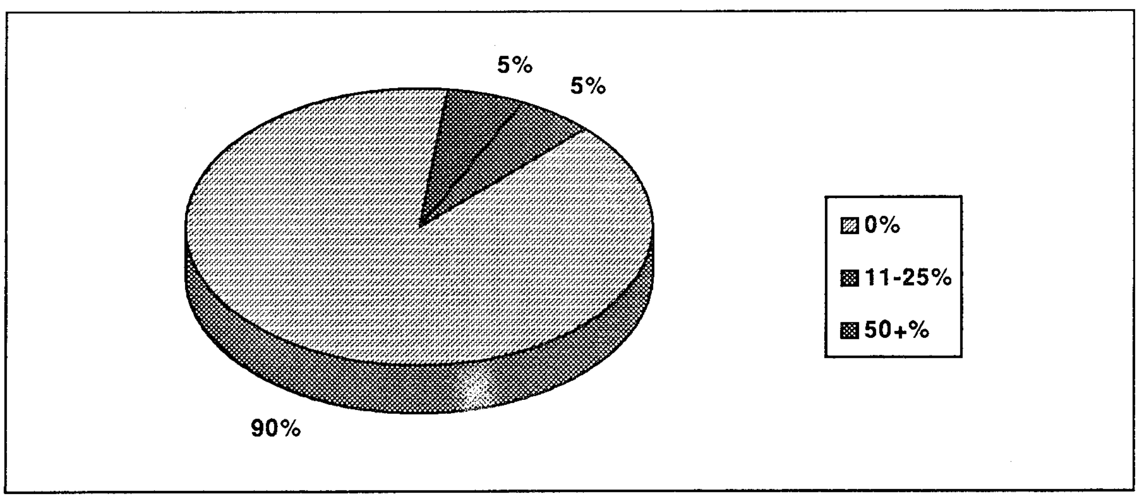

FIGURE 12 Market Share in Sample Technology Area - SBIRs

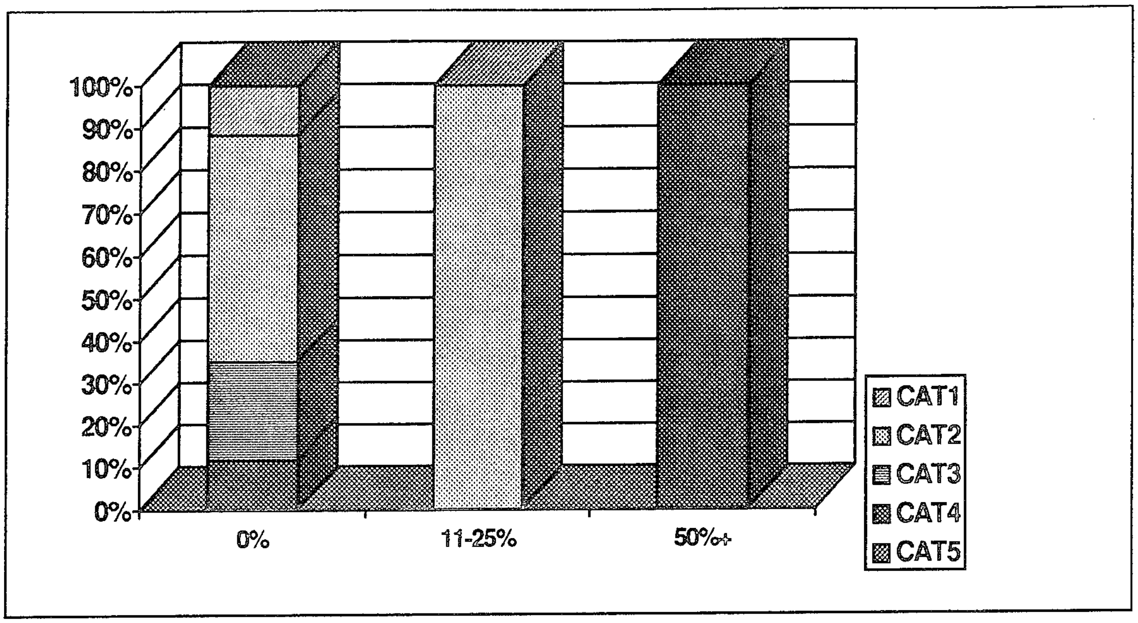

FIGURE 13 Degree of Commercialization by Market Share - SBIRs

Number of Employees - CRDAs. The sample CRDA partners exhibit a much greater size range in terms of both the number of employees and market share. As shown below, firms range in size from as few as five employees to as many as 325,000 with a significant number of firms across a broad spectrum of size.

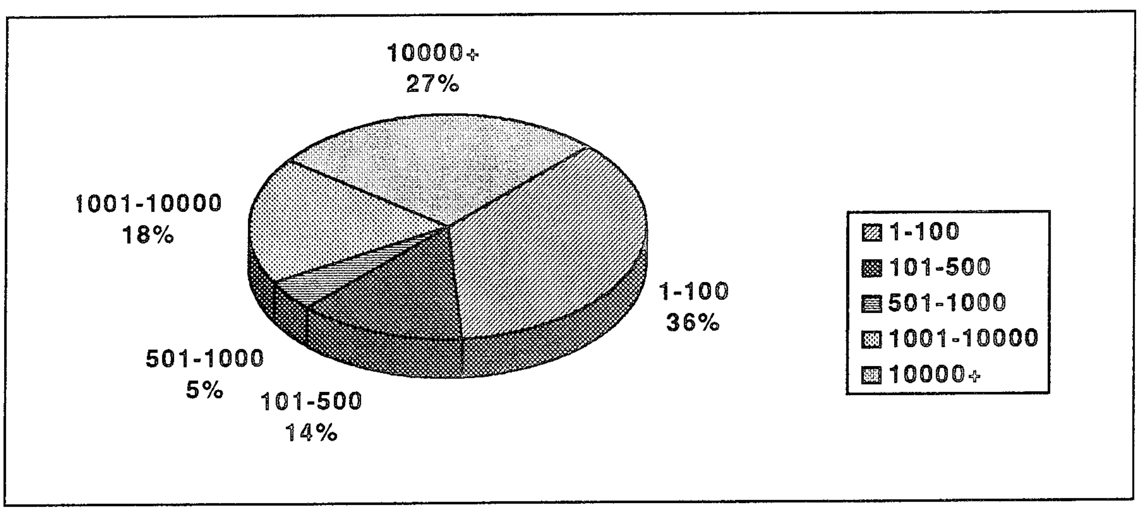

FIGURE 14 Number of Employees - CRDAs

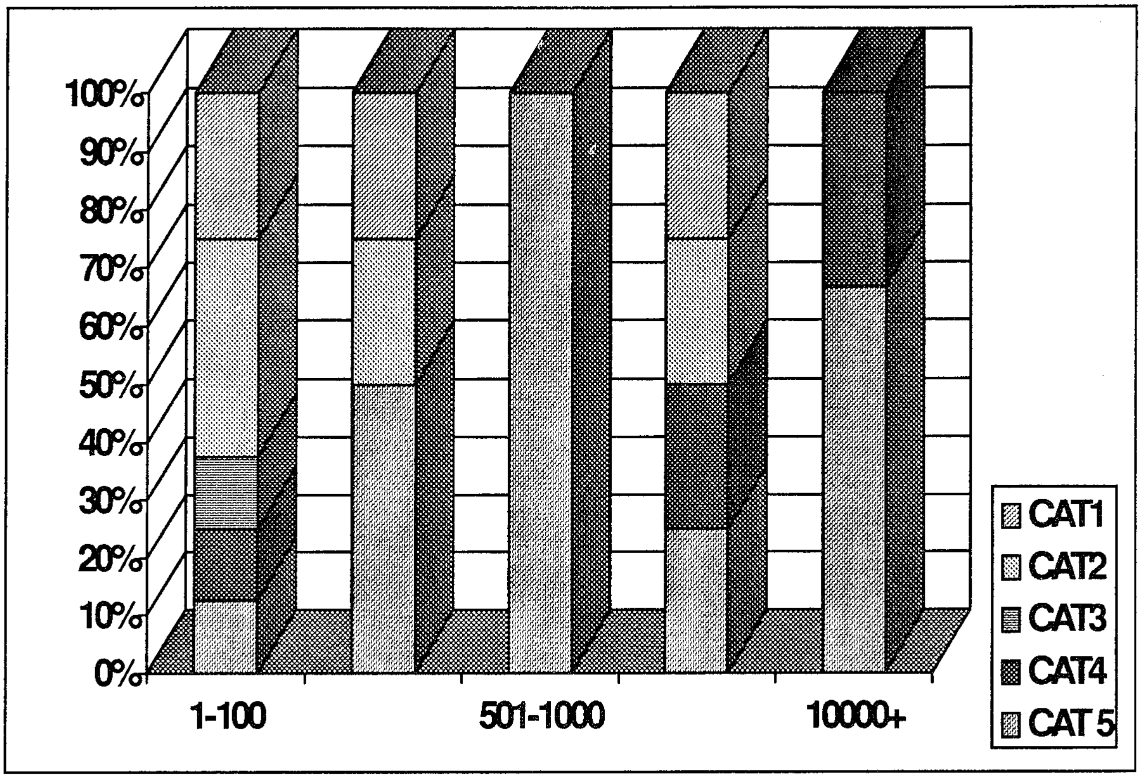

FIGURE 15 Commercialization by Size (Number of Employees) - CRDAs

Due to the extremely large size of some of the sampled CRDAs, several possible outliers exist in this data. However, after careful consideration of each case, only the very largest firm is removed before performing regression analysis. Removal of this firm is justified because it is more than five times greater than the next three largest firms in terms of the number of employees, thereby exerting a disproportionate effect on the fitted regression line.

Regression analysis in Appendix C (p C-3) indicates that a significant relationship exists between the number of firm employees and the degree of commercialization achieved for products resulting from the sample CRDA. Moreover the sign of the coefficient suggests that smaller firms achieve a greater degree of commercialization than larger firms.

Anecdotal evidence gathered from the sample CRDA partners reveals that many smaller firms enter into CRDAs for the purpose of obtaining technology necessary for a product the firm intends to market in the near term. In all but one case, the sample small firms (500 employees or less) seek technology characterized as being in the advanced development stage. On the other hand, four out of eleven large firms classified the transferred technology as being in the exploratory development or basic research stage. Moreover, the large firms generally entered into the CRDA either to gain process technology that would improve their ability to produce an end product, to refine a subsystem to improve a product they currently produce, or to gain Air Force evaluation of technology they already possess.

The results of this study supports Audretsch's assertion that small firms better innovate in high technology industries, such as electrotechnology, where an incremental improvement in capability potentially creates a new product market (4). Additionally, as Radosevich and Rosen observe in their studies, the large firms innovate by attempting to add on to existing technologies that meet the needs of well-established markets (19, 21).

Market Share - CRDAs. The relative measure of firm size, market share, ranging for CRDAs from a low of zero for half of the sample up to a single firm possessing 100% of their market, offers little insight for CRDA partners, as well. In 11 out of 23 cases the firms did not possess a market share for the technology that is the subject of their CRDA. Multiple regression analysis found no significant relationship between the CRDA partner's market share and the degree of commercialization of their project's technology.

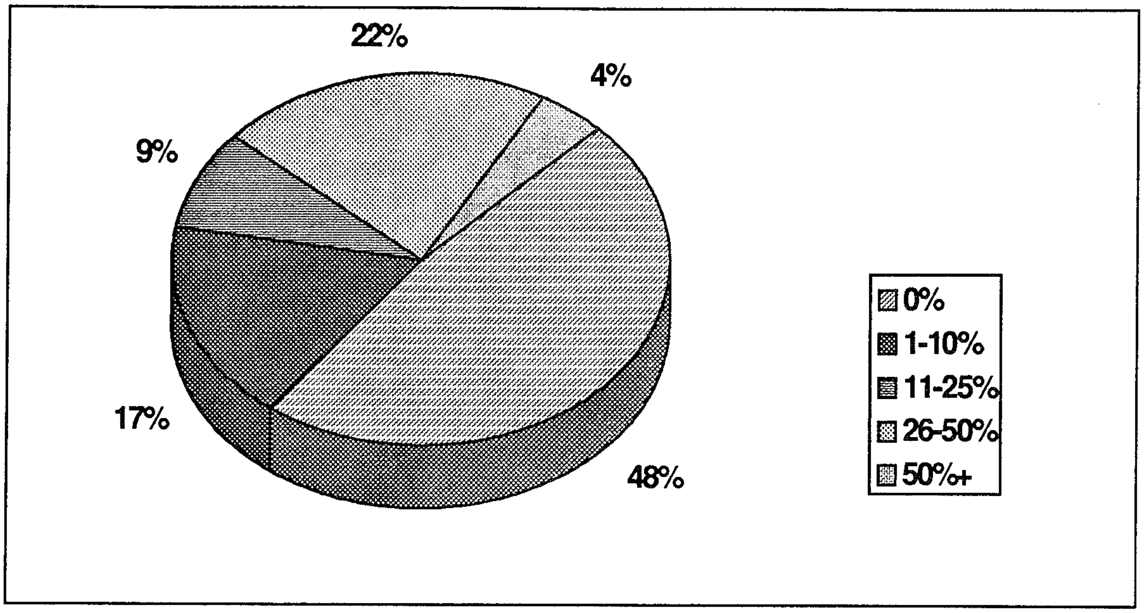

FIGURE 16 Market Share - CRDAs

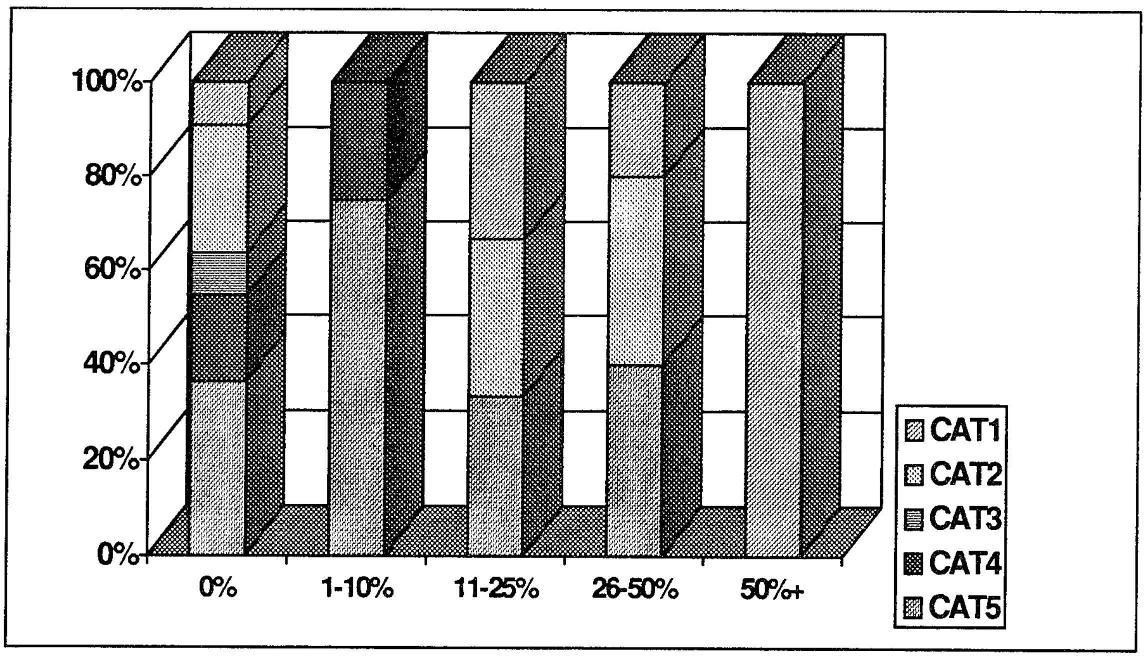

FIGURE 17 Commercialization by Market Share - CRDAs

Innovation Experience

This study examines three measures of innovation experience. It asks if the cumulative past experiences of working with unique government procedures and policies contributes significantly to the firm's commercialization outcome. Second, the study examines the number of innovation agreements with educational institutions and other private firms to determine if the cumulative past experiences of partnering for the purpose of innovating and commercializing technology contribute to the firms ability to commercialize technology under the current agreement. Third, as a measure of the firm's experience with the commercial marketplace, the study investigates the firm's sales to the private sector as a percentage of its total sales.

Prior Government Innovation Experience - SBIRs. The SBIR contractors' prior government innovation experience consists almost exclusively of Phase I and II SBIR contracts completed prior to the sampled contract.

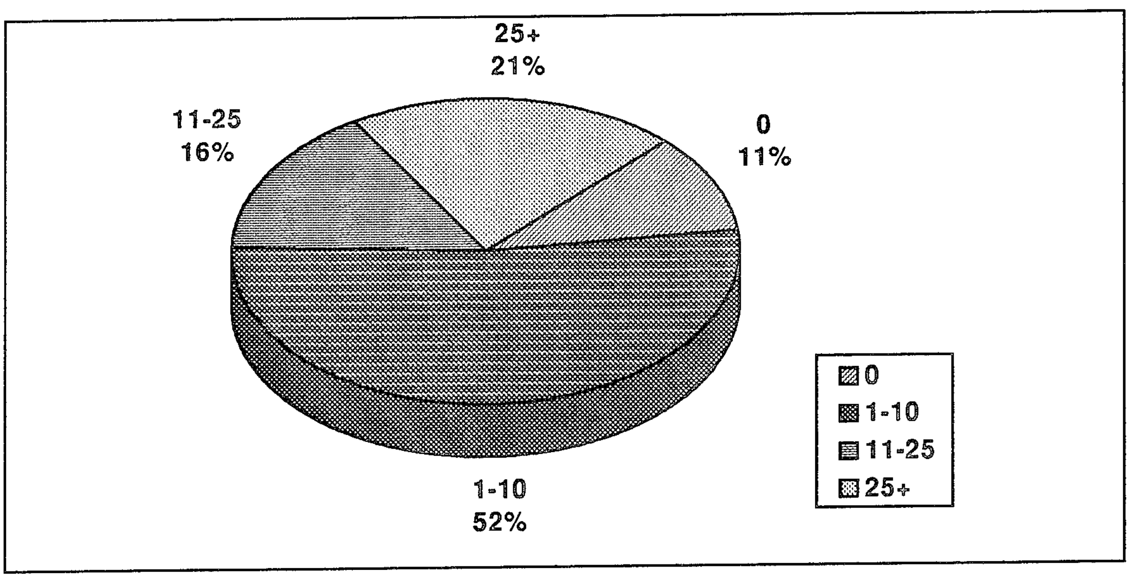

FIGURE 18 Government Innovation Experience - SBIRs

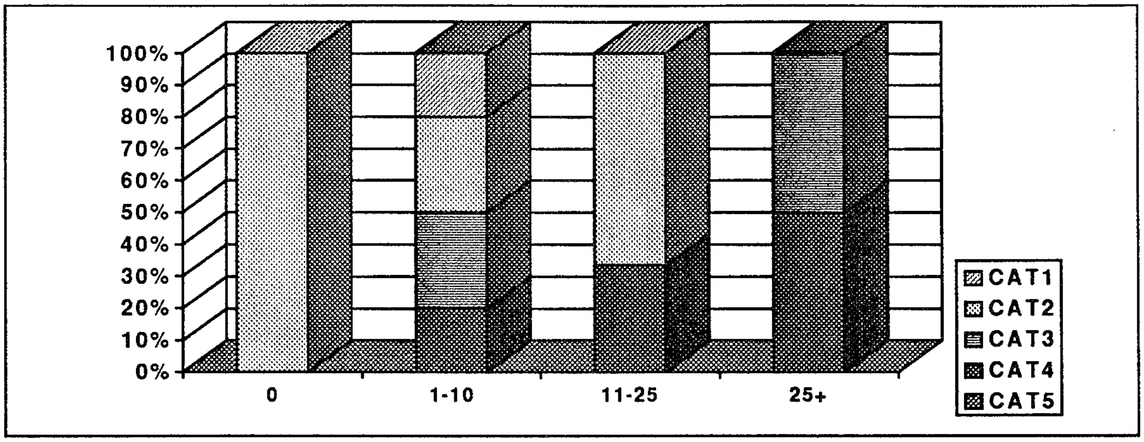

FIGURE 19 Commercialization by Government Innovation Experience - SBIRs

The experience level ranges from no prior government contracting experience in the case of two firms to a high of 110 SBIR contracts completed prior to the sample contract. Multiple regression analysis reveals no significant relationship between this variable and the degree of commercialization achieved. In response to an interview question, most of the SBIR contractors indicate that working with the Air Force through the SBIR process of solicitation, award and performance went smoothly and is not complicated. This information suggests that learning, in the context of the SBIR process is not a significant factor in the commercialization of technology developed under it. Perhaps the significance of the process lies in its simplicity, so that the administrative interface with the government does not hinder commercialization. Another possibility cites the Air Force's lack of knowledge of the commercialization process so that past experience with the Air Force SBIR process does not imply that the participating contractors learn to fully develop and market products.

Private Innovation Experience - SBIRs. The private innovation experiences of the SBIR contractors consists of establishing formal agreements with another private firm or educational institution for the purpose of sharing technology and commercializing a product or process resulting from that sharing.

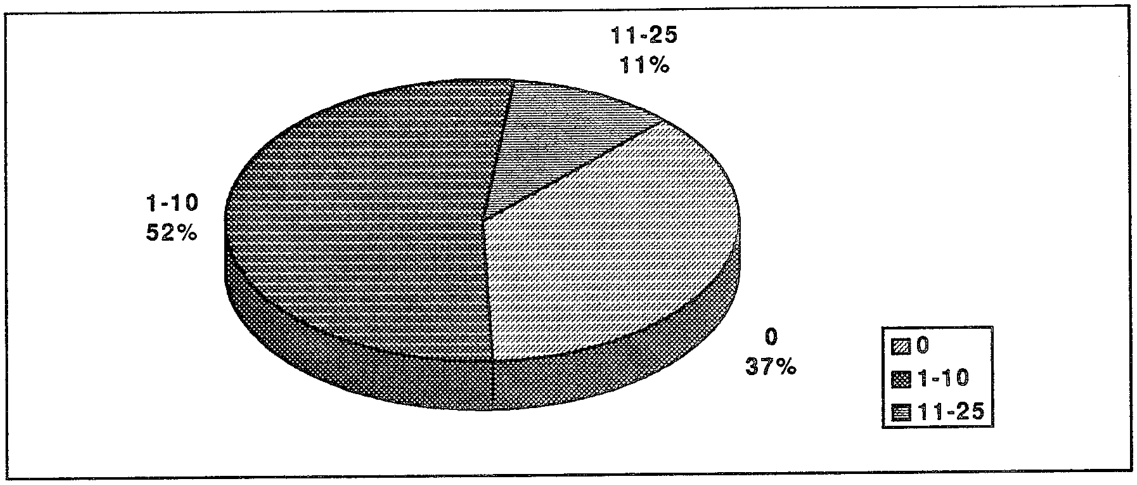

FIGURE 20 Private Innovation Experience - SBIRs

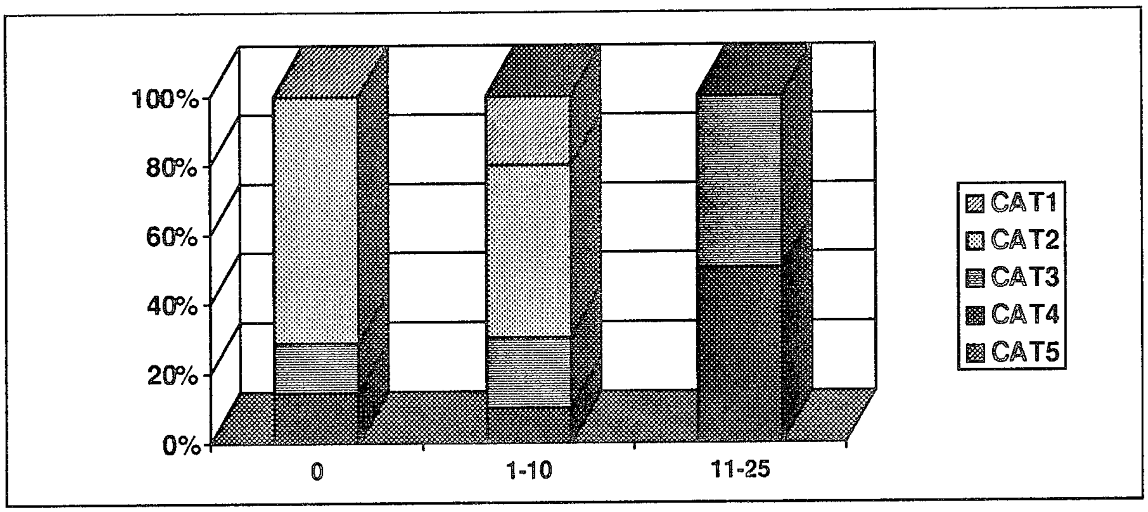

FIGURE 21 Commercialization by Private Innovation Experience - SBIRs

A large portion of the sampled contractors possess no or limited experience with commercial innovation resulting from another private source. However, multiple regression analysis suggests that a firm's private innovation experience significantly relates to the degree of commercialization (Appendix C, page C-2). The sign of the coefficient for the private innovation experience variable indicates that as firms gain private

partnering experience, the degree of commercialization achieved increases. This result is consistent with learning curve theory suggesting that as firms repeatedly team to innovate, develop, produce, and market a product, they gain valuable experience that improves their ability to commercialize the results of future projects.

Private Sector Orientation - SBIRs. Over 60% of the sampled SBIR contractors make 30% or less of their sales to the private sector, while the remainder split their sales about evenly between the private sector and government sales. Multiple regression analysis finds no significant relationship between a firm's private sector orientation and the degree of commercialization achieved for the sampled SBIR project. This is an interesting result because several personnel from the sampled SBIR firms identify the process of commercializing a product for a private sector market as a skill they wish to develop in their firm. One expects that those firms with strong private sector sales would understand this process better than those SBIR contractors that conduct a substantial portion of their business with the federal government. However, this study finds no significant differences based on private sector sales experience.

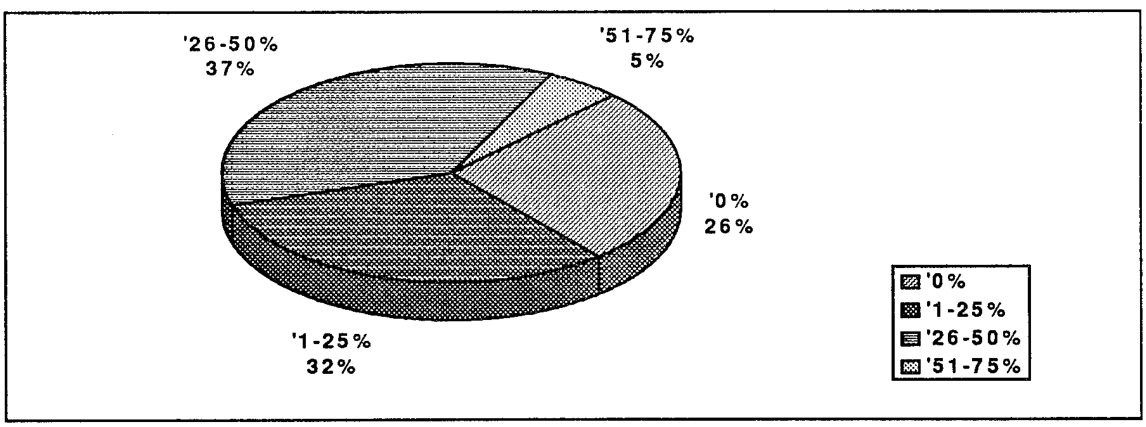

FIGURE 22 Private Sector Orientation - SBIRs

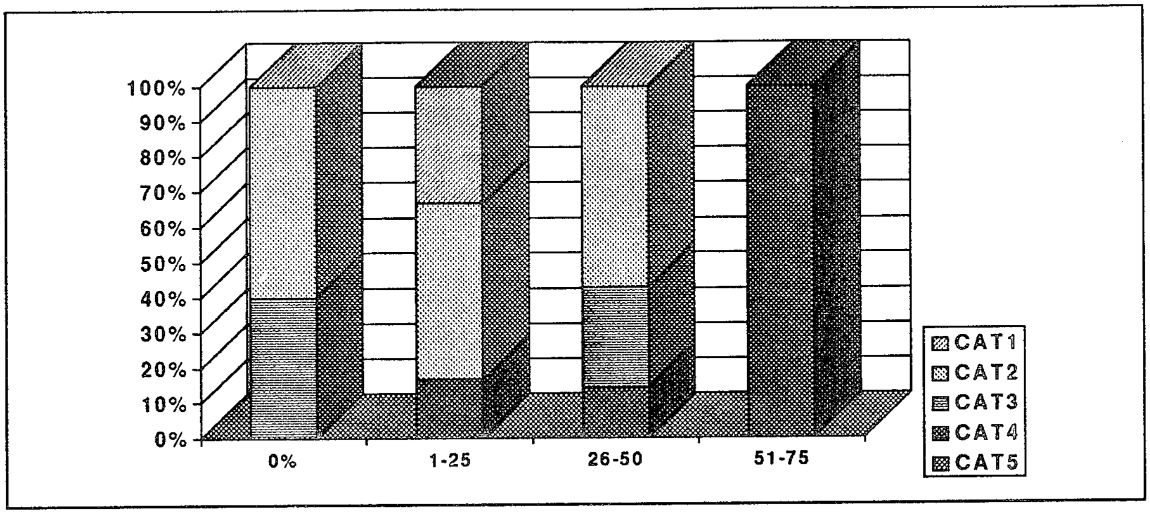

FIGURE 23 Commercialization by Private Sector Orientation - SBIRs

<u>Government Innovation Experience - CRDAs</u>. Most CRDA partners possess no prior innovation agreements with the federal government. Generally those partners with prior experience fall into two categories. Traditionally defined small businesses (500 employees or less) have participated in the SBIR program, while large businesses' experiences consist primarily of research grants. Multiple regression analysis indicates that no significant relationship exists between government innovation experience and the degree of commercialization achieved in the sample CRDA projects.

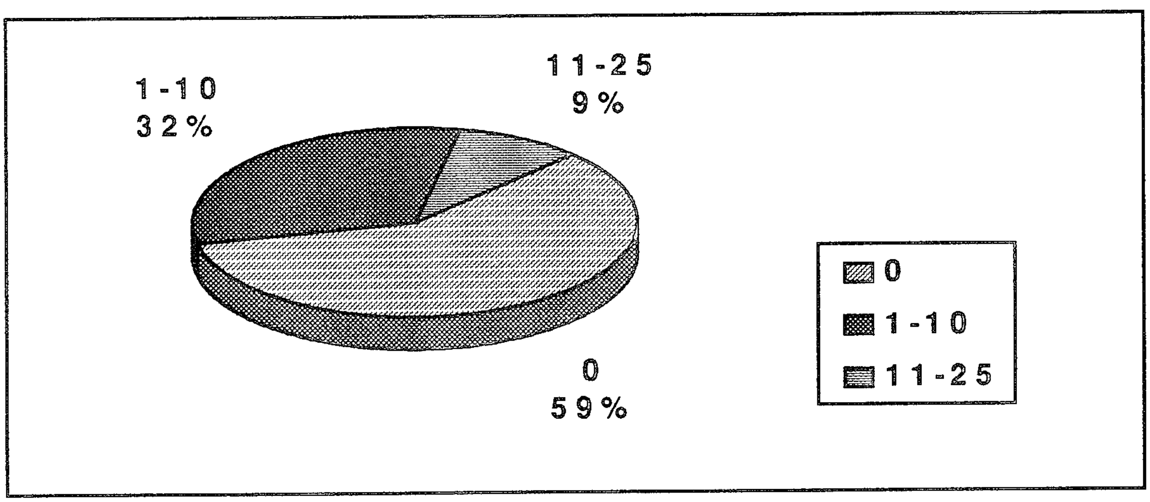

FIGURE 24 Government Innovation Experience - CRDAs

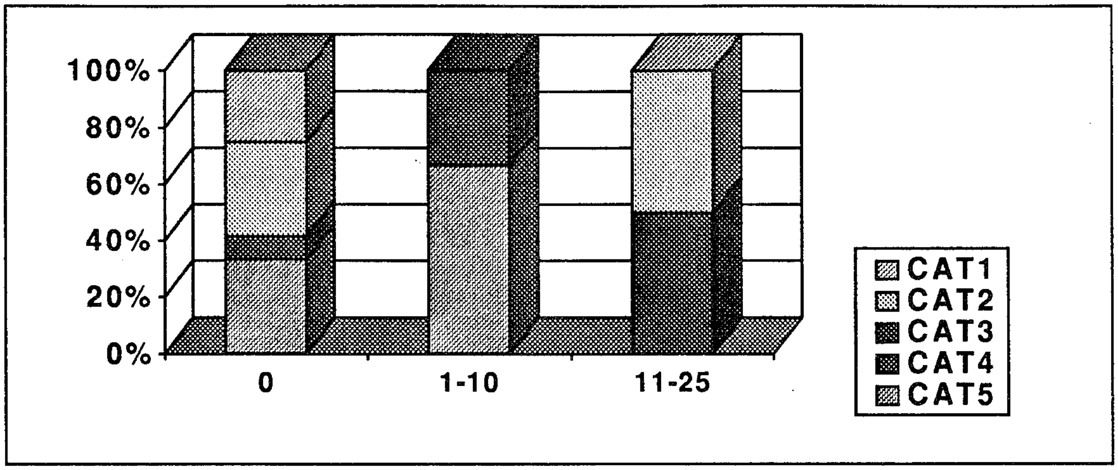

FIGURE 25 Commercialization by Government Innovation Experience - CRDAs

However, interviews with the sample CRDA partners indicate that learning curve theory strongly applies to the process of negotiating and participating in a CRDA with the Air Force. The time frame for the sampled CRDAs, 1991-1993, examines the process at its inception across the Air Force. Many firms indicate that the sample CRDA is their firm's first. In some cases, the CRDA is also the Air Force organizational partner's first CRDA. Interviews with both Air Force and firm partners reveal a very complicated negotiation process driven by legal concerns for sharing risks and reward. In many cases, consummation of an agreement took the parties six months to one year. In some cases, after finalizing the agreement, one or both parties failed to complete the work agreed to, so that no end result ever occured. Interestingly, in these cases, neither party considers a legal remedy which is pro forma under traditional government contracting.

The problems with the process indicate that learning can certainly improve it. The limited time frame of the sample fails to capture any improvement in the process over time. Additionally, several firms mentioned the need to improve the process because a driving concern for them involves the time to market for any product resulting from the

agreement. These firms expected the CRDA process to allow them to market their product sooner than any competitors, thereby allowing them a competitive advantage.

Private Innovation Experience - CRDAs. Multiple regression analysis indicates that private innovation experience is not significantly related to the level of commercialization achieved under the sampled CRDAs. The private innovation experiences of the CRDA partners consist of formal agreements established by the contractor with another private firm or educational institution for the purpose of sharing technology and commercializing a product or process resulting from that sharing. Seventy percent of the sampled contractors possess no or limited experience with commercial innovation resulting from another private source. The four firms possessing the most private innovation experience achieve very little commercialization. Interviews reveal that two of the four entered into the CRDAs with the Air Force to gain access to technology to be applied to long term development projects. The remaining two partners entered into the CRDAs with the Air Force for the purpose of independently testing existing products.

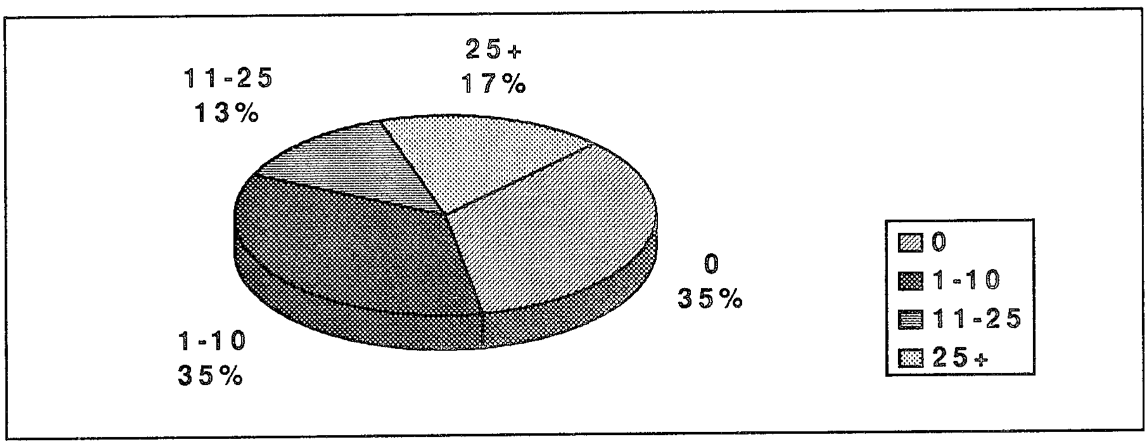

FIGURE 26 Private Innovation Experience - CRDAs

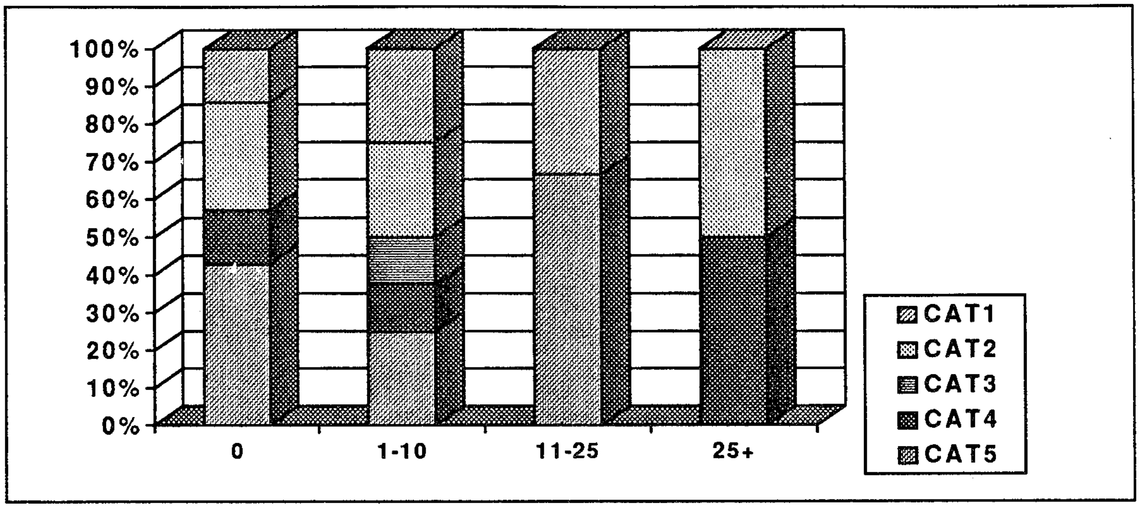

FIGURE 27 Commercialization by Private Innovation Experience - CRDAs

Private Sector Orientation - CRDAs. Multiple regression analysis indicates that the CRDA partners private sector orientation as measured by the percentage of sales made to private commercial customers is not significantly related to the level of commercialization achieved under the sampled CRDAs.

However, a more detailed examination of the data reveals an interesting trend. Seven of the sampled firms make greater than 50% of their sales to the private sector. Four of these seven firms, among the largest sampled with over 30,000 employees each, achieve commercialization levels of only four or five for the sample CRDAs. Of these four very large firms, one entered into the CRDA with the Air Force for the purpose of independently testing their product, one to allow the Air Force free access to their product for marketing purposes, one to gain access to technology for very long term development (15+ years), and one abandoned the CRDA before completion.

In contrast the three remaining firms, each possessing private sector sales of over 50% of their total sales, employ less than 200 people. All three entered into CRDAs for

the purpose of gaining access to technology for products their firms are developing for immediate commercialization. At the time of this survey one firm possessed an established market for a product derived from the CRDA, one firm made sales to the government and is cultivating private markets, while the third is beta testing its innovation for introduction into a market niche of which they currently possess 50%.

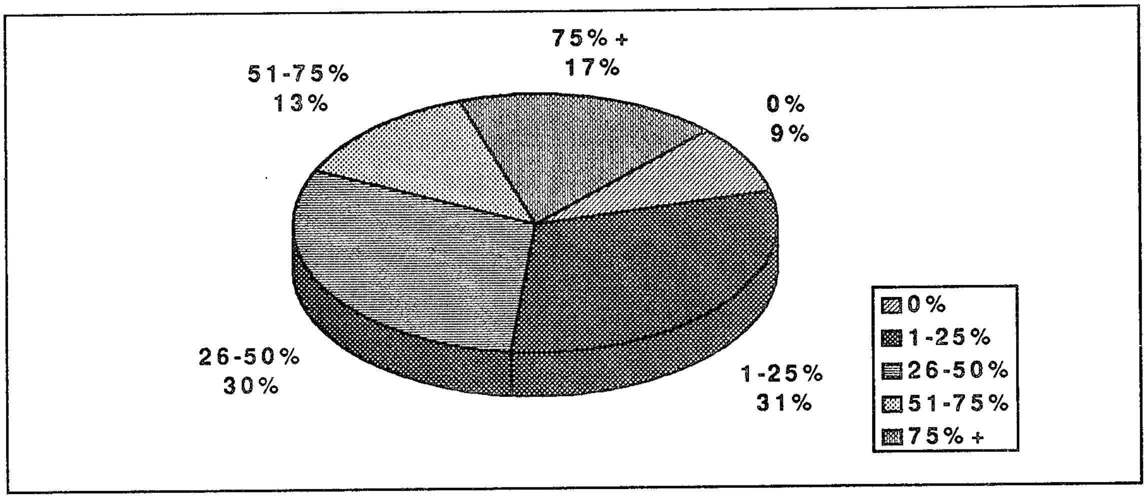

FIGURE 28 Private Sector Orientation - CRDAs

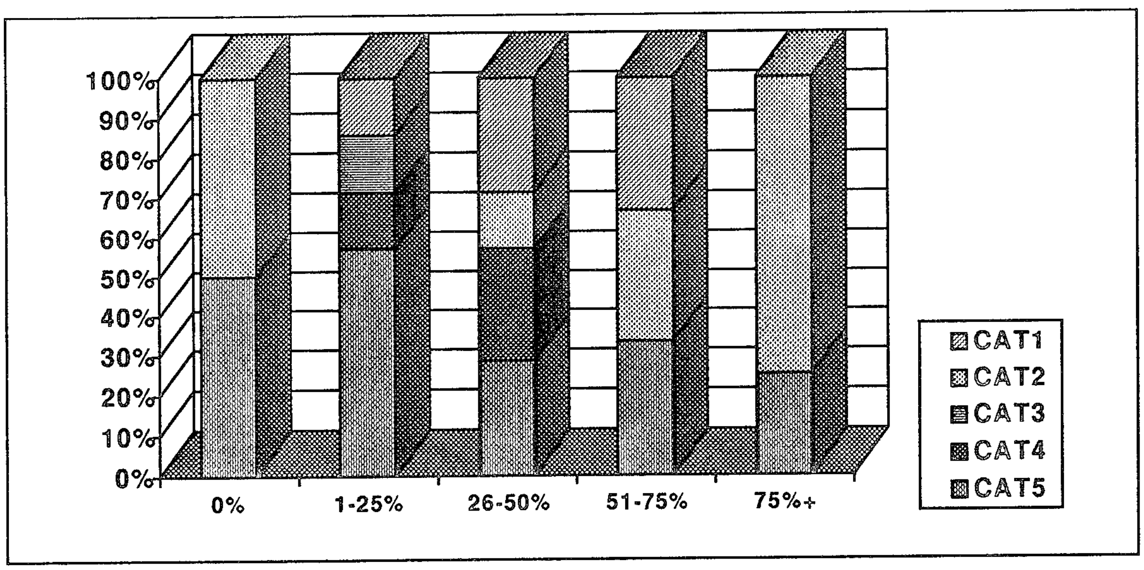

FIGURE 29 Commercialization by Private Sector Orientation - CRDAs

Technology Area Experience

Technology area experience measures the number of years a firm has participated in the technology area to which the innovation is applied prior to entering into the sample agreement. The data collected does not reflect a sample firm's experience with the technology area from which the innovation is derived.

Technology Area Experience - SBIRs. All of the sample SBIR contractors except for three possess at least three years experience in their SBIR's subject technology area prior to entering into the sample contract. Multiple regression analysis did not find any significant relationship between a firm's experience with a technology area and the degree of commercialization achieved under the sampled SBIR contract.

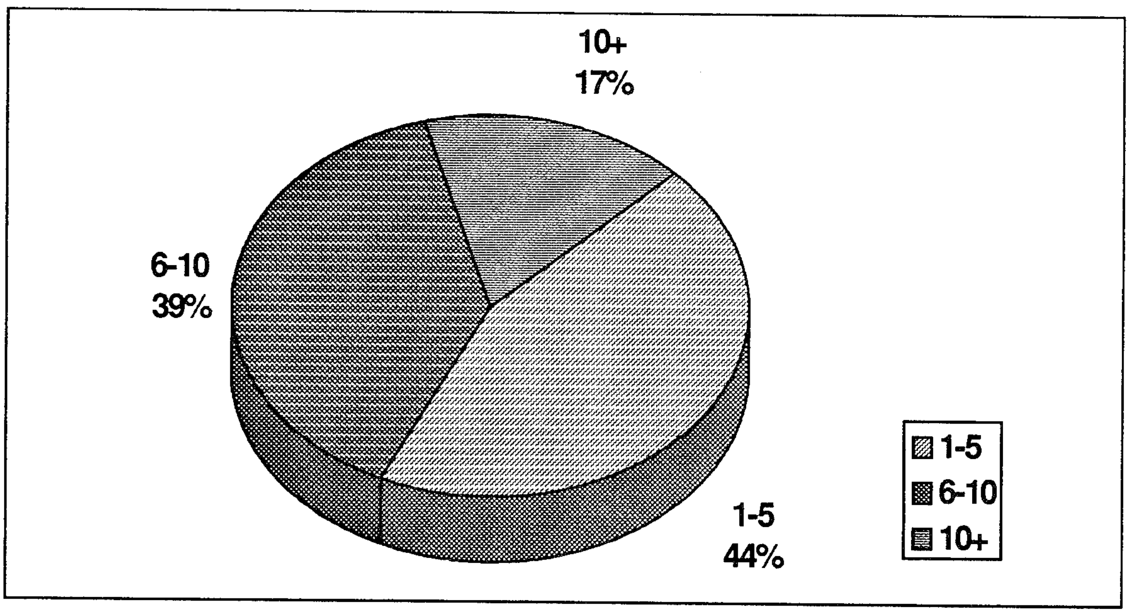

FIGURE 30 Technology Area Experience - SBIRs

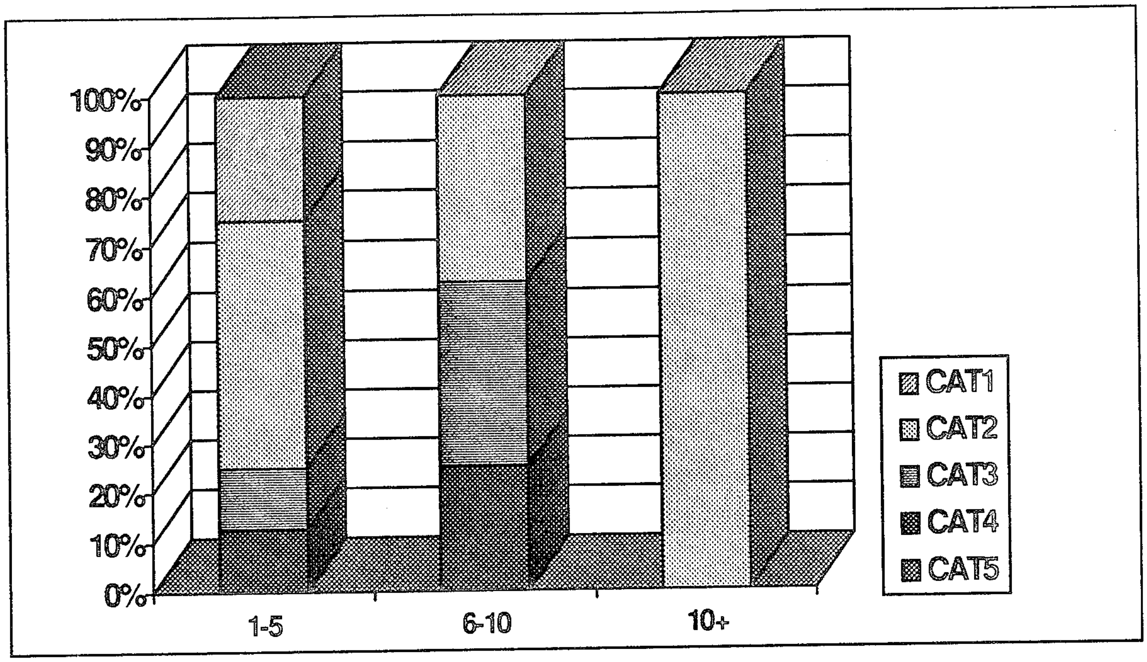

FIGURE 31 Commercialization by Technology Area Experience - SBIRs

Technology Area Experience - CRDAs. All of the sample CRDA partners except for three possess at least three years experience in their CRDA's subject technology area prior to entering into the sample CRDA. Ten possess over 20 years in the sample technology area. Multiple regression analysis indicates that technology experience is significantly related to the degree of commercialization achieved for the sampled CRDAs. Again, it is important to note that the variable, prior technology experience, measures the sample firm's experience in the technology area to which the innovation developed under the sampled CRDA is applied rather than experience in the technology area from which the innovation arose. This researcher proposes that this variable is significant for CRDAs but not for SBIRs because the SBIR process evaluates projects for factors including the firm's experience in the project's technology area and selects only those firms possessing a high degree of this quality.

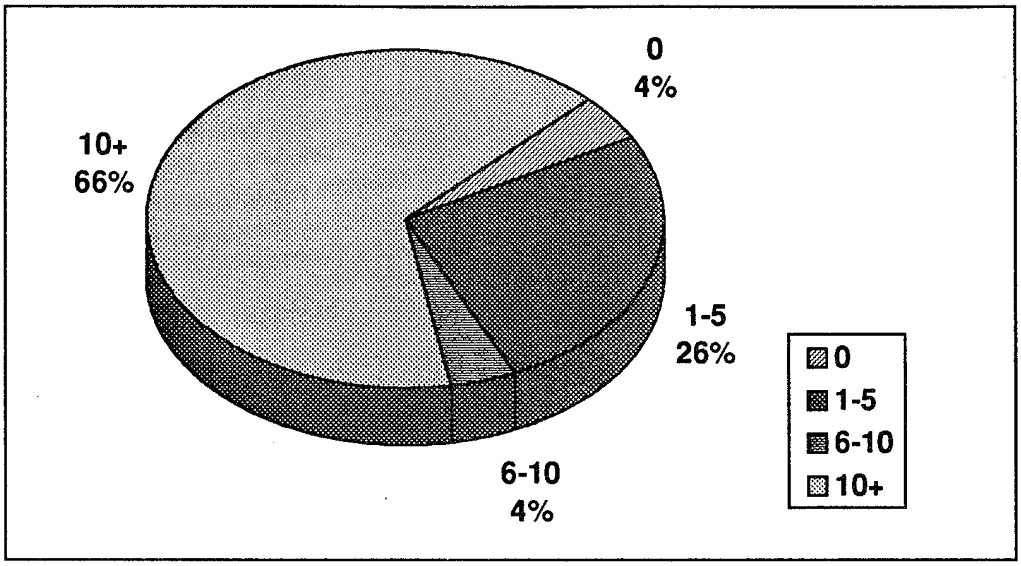

FIGURE 32 Technology Area Experience - CRDAs

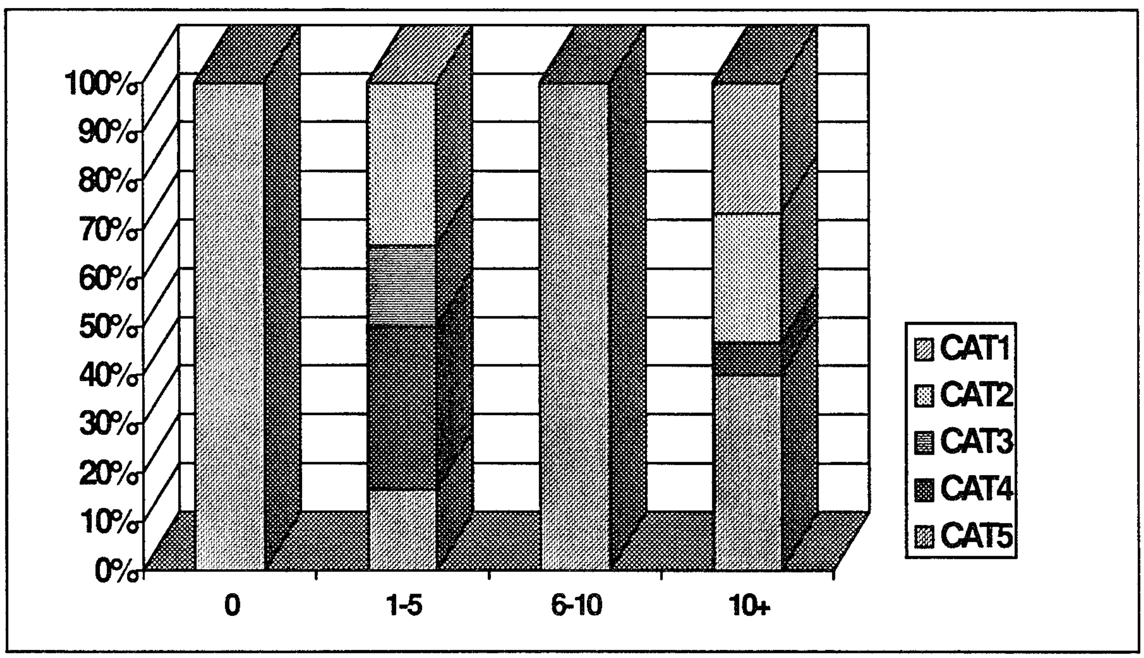

FIGURE 33 Commercialization by Technology Area Experience - CRDAs

Maturity of Technology

This study gathers data regarding the firm's evaluation of the maturity of the technology they sought to utilize to develop their product or process for commercialization. In the case of SBIR contracts, the contractor evaluated the level of prior research and development done in the specific technology area at the inception of the sampled SBIR contract. The CRDA partner evaluates the level of research and development from which it began working with the Air Force under the sample agreement. The firms apply one of three ratings to their situation: (1) Basic R&D - fundamental investigation of new ideas and scientific principles; (2) Exploratory Development - the assessment of scientific and technological advances warranting further examination for use in a product area, or; (3) Advanced Development - demonstration of a prototype (30:102). This researcher adds a fourth category, fully mature technology, after interviewing two CRDA partners whose agreement with the Air Force consists solely of marketing fully developed Air Force products.

Maturity of Technology - SBIRs. All of the sample SBIR contractors rate the technology level of their project as either exploratory development or advanced development. Multiple regression analysis finds the maturity of the technology transferred significantly relates to the degree of commercialization achieved from the sampled project. This result corresponds to Markusen's and Malecki's proposals that more mature technological innovations reduce development costs to the firm, increasing the incentive to commercialize. Additionally, more mature technological innovations reach the market and establish market share quicker, adding to the profit incentive.

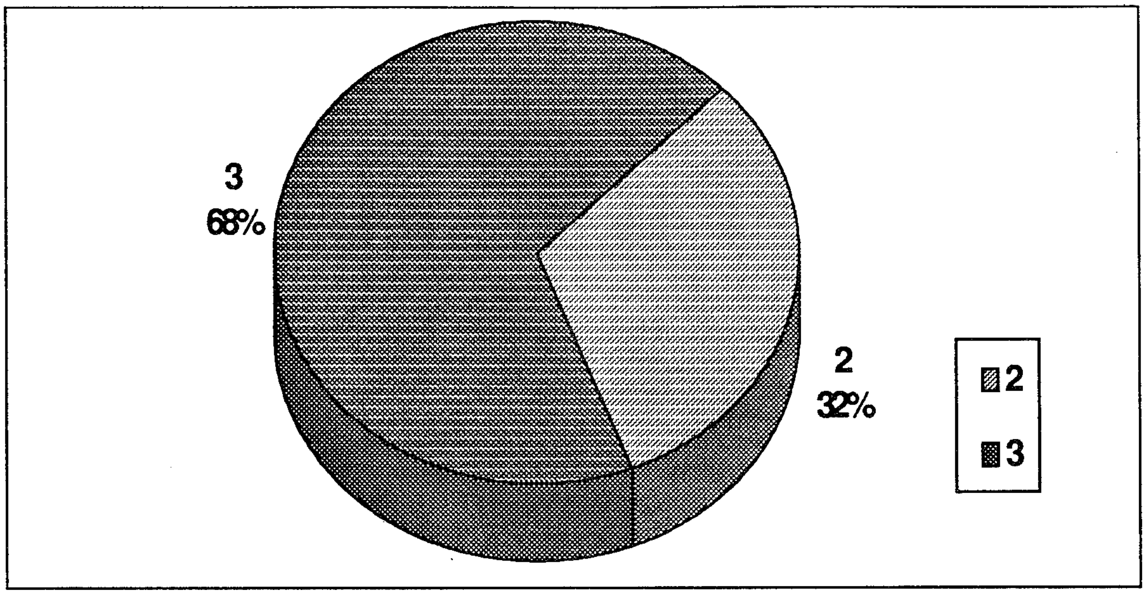

FIGURE 34 Maturity of Technology - SBIRs

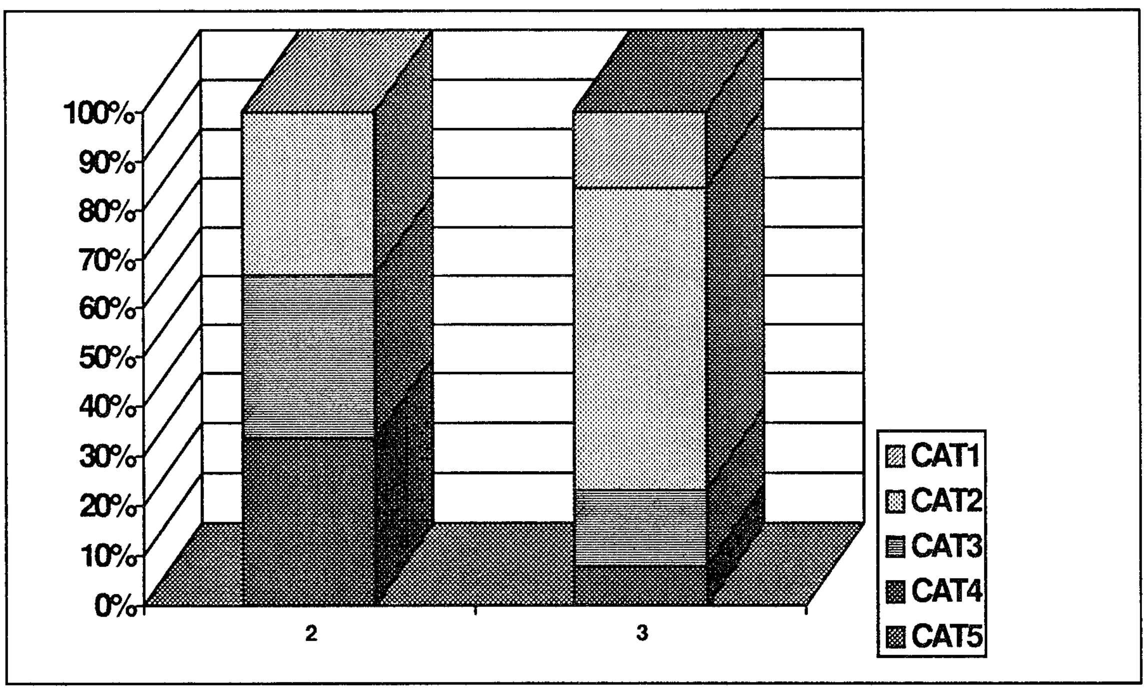

FIGURE 35 Commercialization by Maturity of Technology - SBIRs

Maturity of Technology - CRDAs. As with the sample SBIRs, the sample CRDA partners generally rate the maturity of the R&D on their respective projects as either exploratory development or advanced development. However, one firm rated the technical maturity as basic research and two other firms received fully mature technology. Performing multiple regression analysis on the entire sample results in no significant relationship between the maturity of the technology and the degree of commercialization. However, one must note that some of the CRDA partners did not enter into their agreements with the intent to immediately attempt to commercialize any result and still others did not complete the requirements of the agreement. Removing these cases leaves a sample consisting of CRDA partners possessing the intent to apply the results of the agreement to the development of a product or process for commercialization. Completing the multiple regression analysis a second time reveals that the maturity of the technology significantly relates to the degree of commercialization resulting from the sample projects (Appendix C, page 3).

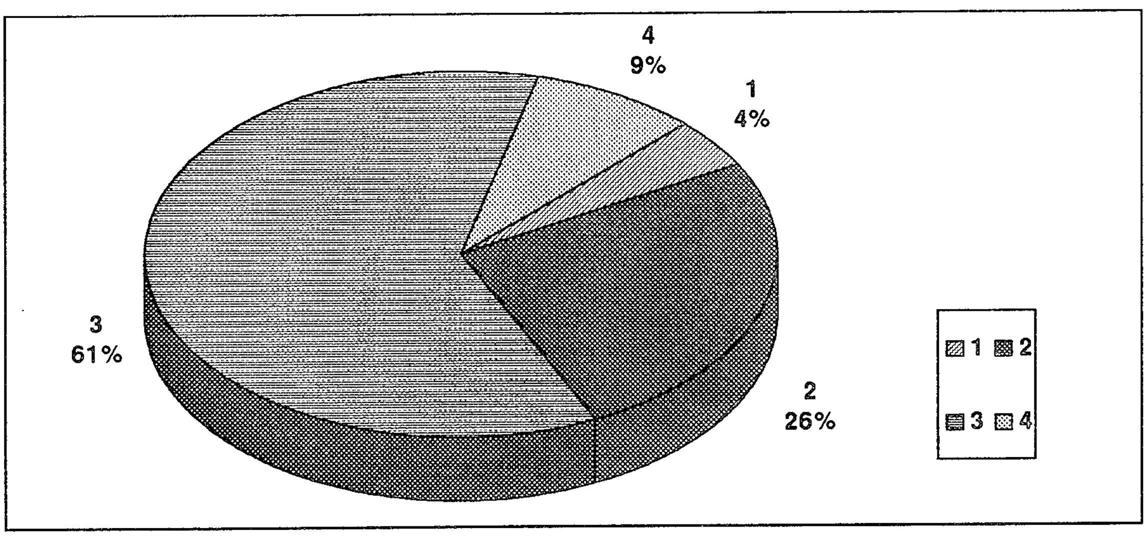

FIGURE 36 Maturity of Technology - CRDAs

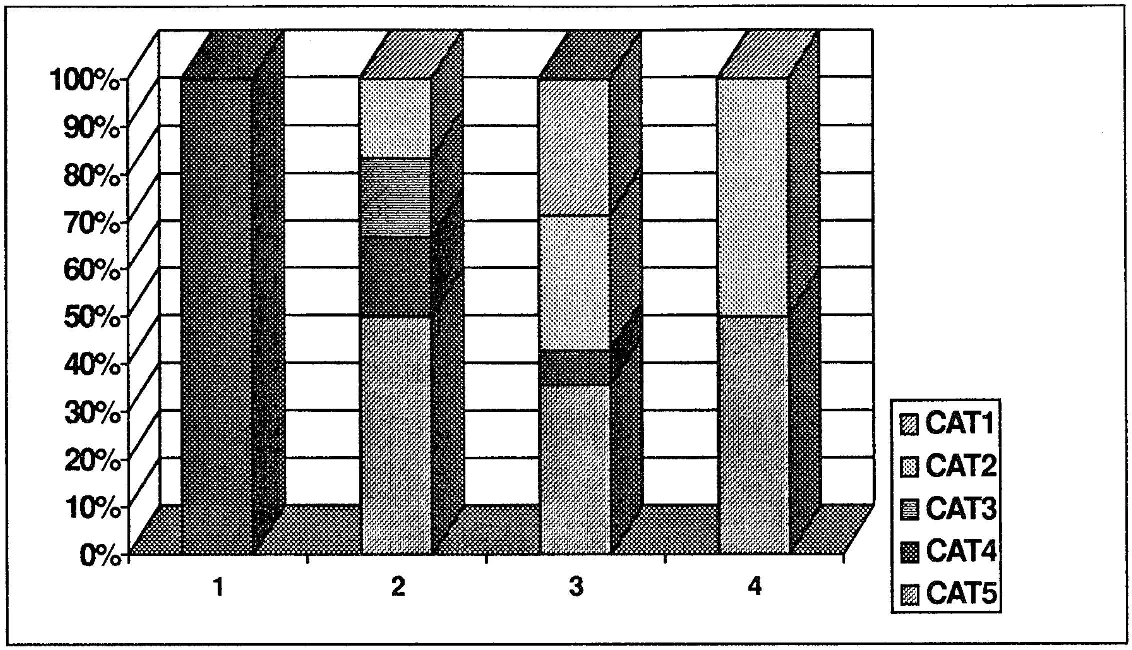

FIGURE 37 Commercialization by Maturity of Technology - CRDAs

Conclusion

In summary, two of the variables examined in this study are significant for all cases of innovation agreements with the Air Force. First, the SBIR agreement type resulted in a greater degree of commercialization as measured by this study. However, this result must be tempered by the recognition that the CRDA agreement type generated a relatively greater number of fully commercialized products. Secondly, the greater the maturity of the technology involved in the transfer, under both agreement types, the greater the success of the commercialization effort.

Other variables are significant for one or the other agreement type, but not both. First, the more private teaming done by SBIR contractors prior to attempting commercial innovation with the Air Force, the greater the commercialization achieved under the sampled SBIR contract. Interestingly this result was not found for the CRDA partners.

However, the lack of intent to commercialize products or processes resulting from a number of the sampled CRDAs may have affected the result for this variable.

The more experience possessed by a CRDA partner in the technology area to which the innovation was applied, the greater the degree of commercialization achieved. While many SBIR contractors also hold a great deal of experience in the sampled SBIR's technology area, the experience variable was not significant for this sample. No explanation can be provided for this result.

The fact that firm experience in dealing with the government for the purpose of teaming for innovation is not significant to the commercialization of technology resulting from the sampled projects is interesting. In the case of SBIR contracts, the process appears to be well-defined so that learning is less of a factor for successful completion of a SBIR contract. In the case of CRDAs, many of the sampled partners complained of process problems. However, experience with the process, as measured in this study, does not significantly affect the outcome of the commercialization effort.

Chapter Five utilizes the results of this data analysis, as well as the anecdotal evidence gathered from this study's interviews to formulate some general recommendations to improve the Air Force's technology transfer process. Moreover, it presents several areas that require further research as a result of additional questions that surfaced during this study.

V. Conclusion

Introduction

Analysis of the survey data reveals several firm characteristics that relate significantly to the degree of commercialization the sample firms achieve under their respective projects. Additionally, the interviews with project managers and owners of the sample firms highlight some common observations and recommendations regarding the Air Force's SBIR and CRDA process. This chapter translates these findings into several recommendations to improve the Air Force technology transfer process to maximize the use of Air Force resources for commercial development. Additionally, after collecting and analyzing this study's data, this researcher is left with questions that did not exist when the study began. This chapter briefly explains several future research possibilities stemming from some of these questions.

The table below summarizes the significant findings of this study.

TABLE 2 Significant Findings

AGREEMENT TYPE	SIGNIFICANT RESULT
SBIR Contract	Contract type more conducive to commercialization than CRDA
SBIR Contract	Past private innovation experience positively related to commercialization
SBIR Contract	Maturity of technology received positively related to commercialization
CRDA Agreement	Contract type less conducive to commercialization than SBIR
CRDA Agreement	Absolute firm size negatively related to commercialization
CRDA Agreement	Firm experience technology area to which innovation applied positively related to commercialization
CRDA Agreement	Maturity of technology received positively related to commercialization

The most significant results include finding that the structure of the mechanisms significantly influences the outcome of the innovation project. The SBIR process and mechanism ensures some development occurs in almost all projects, but fails to bring as many to full fruition. The CRDA process results in many more projects ending without any commercialization prospects, but it also results in more fully commercialized products.

The significance of firm size must be tempered by the motivations of the firms pursuing the project. Several large CRDA partners did not enter the process with the intent to seek commercialization. Several of the largest firms that did seek commercialization possess development plans that stretch over decades, tempering the rating of the degree of commercialization for their project. This same observation affects the significant result for technology maturity. Again many large firms pursued CRDAs with more basic research objectives that may later blossom into significant markets. Meanwhile, many smaller firms seek to exploit available market niches. Government policy makers must evaluate their resources and decide how their technology can best be developed by the private sector.

Logical cause and effect explanations support the last two significant results: private innovation experience and technology area experience. However, the mixed results for these variables after stratifying the data by agreement type require further research to ensure their validity. From these findings and the observations resulting from the interviews with CRDA and SBIR firm project managers and owners, several recommendations to improve the Air Force technology transfer process are made.

Recommendations

CRDAs. The following recommendations are made with the knowledge that every SBIR and CRDA is unique in its background and potential. The Air Force and private firms engage in some projects with the forethought that no immediate or

quantifiable commercialization will result from their efforts. The recommendations below aim strictly at those many cases in which the Air Force expends resources on technology which promises relatively short-term commercialization possibilities.

Considering the significant difference in the commercialization outcome between the sample SBIRs and CRDAs, the characteristics of the two transfer mechanisms should be considered for their affect on this outcome. While SBIR contractors face performance risk when dealing with the government, their cost risk is minimized up to the value of the contract. In contrast, CRDA partners face cost risk when pursuing joint development projects, but their performance risk is minimal because they can abandon the project without consideration to the Air Force. The unique qualities of both of these agreements provide unique advantages to the Air Force and its partner. Blending their qualities may enhance the commercialization opportunities under each mechanism.

The first recommendation derived from SBIR contract characteristics for improving the CRDA process is to formalize a procedure for screening and selecting CRDA partners that demonstrate qualities positively related to commercializing Air Force technology. For instance, this study finds that factors such as firm size, technology area experience, and the maturity of the Air Force technology all affect the CRDA outcome. Panels of Air Force experts can apply these criteria and others to select those projects that demonstrate the greatest promise for realizing full development. In some of the sample CRDA cases, it is apparent that the Air Force gave no consideration to the firm's capabilities or intentions before entering into the CRDA. Consistently, these cases result in stalled or abandoned projects as well as ill will between the project partners. Moreover, the Air Force expends its limited resources on projects that provide no return to it nor to the national economy.

Following closely after screening and selecting potential commercializers, the Air Force should act to strengthen the contractual relationship with the private firm partner.

A commitment of manpower, equipment facilities, etc., even without direct funding, draws upon limited Air Force resources and therefore should be treated as a serious investment for which an appropriate return is expected for the risk assumed. From the interviews, it is apparent that Air Force personnel quickly focus on license fees and royalty payments when negotiating CRDAs, while performance issues for both partners receive less attention. Performance of both parties under a CRDA should be a focus of negotiations consistent with normal government contracting procedures. In seven of the 23 sample CRDAs the inaction of one of the partners results in no commercial result. In four of these seven sample cases, the Air Force fails to meet its commitments under the agreement. CRDA partners should commit to firm goals and timetables in their agreement, to include a business plan that demonstrates their commitment to bring the technology to full commercialization.

An additional observation by several CRDA partners regarding negotiating partnering agreements deserves comment. Many partners complain that the lengthy negotiation process decreases the value of the CRDA experience. A significant result of this study identifies technological maturity as a significant factor in the commercialization of Air Force Technology. A component of technological maturity is the time it takes the firm to get its product to market. Several sample CRDA partners express dismay that the lengthy negotiation process costs them market position. Considering that freedom from cumbersome federal acquisition regulations is a positive attribute of a CRDA, the lengthy negotiation process is reminiscent of complaints about regular government contracts. Two recommendations seek to resolve this problem. First, the basic clauses of the CRDA should be standardized Air Force wide to facilitate understanding of the agreement. Second, Air Force laboratories should seek to staff permanent positions for the negotiation of CRDAs to take advantage of repetitive learning.

Once the parties to the CRDA demonstrate their commitment to pursuing commercialization of Air Force technology, additional resources should be injected into the project for development purposes. This controversial step does not require direct development funding under the CRDA by the Air Force. Instead the Air Force should consider a broad spectrum of initiatives designed to help the firm move from the laboratory to the market. Among these recommendations are involving the SBA for loans to smaller CRDA partners, sponsoring meaningful forums to bring innovators and inventors together, bringing in a middleman to help less experienced firms development a commercial niche, incentivizing other DoD contractors to incorporate CRDA developments into their products to meet AF requirements, and award contracts to CRDA partners for the development and production of products to meet Air Force requirements. A positive example of this type of action from this study involves a very large CRDA partner that decided to abandon the CRDA and the technology area before completion of the project. The large firm's principle investigator sought to continue the project based on its commercial potential and the Air Force officials from the original project agreed. The development of the technology continues under a SBIR contract awarded by the same AF investigators to a small firm created by the principle investigator and his colleagues.

All of these efforts imply a more concerted and uniform effort on the Air Force's part to screen its technology, its current requirements, potential partners, and potential marketplaces. Several commercially successful CRDA and SBIR partners acknowledge that they hapahazardously discovered a market for their product through personal contacts or meetings unrelated to their commercialization efforts. They note a requirement for a wide-ranging forum that enables technology requirements to meet technology offerors. Nascent technology transfer efforts on the Internet suggest great potential for reaching a wide audience, but the effort requires richer on-line information and greater publicity.

SBIRs. While SBIR contractors face many of the same problems that small CRDA partners face when attempting to commercialize their technology, the unique incentive structure of the SBIR program poses some additional problems. SBIR contracts require a deliverable that meets the government's requirement. Several sample SBIR contractors point out that the government's contract requirement and the government's goal of encouraging commercialization are incompatible. They stress the need for government officials to tailor requirements to emphasize commericiality. This point is emphasized by this study's finding that the maturity of the technology pursued under the SBIR contract significantly affects any follow on commercialization.

As noted before, the SBIR process is very good at leading small firms up to the prototype stage of development, but does nothing to promote the leap to commercialization. The actions mentioned above to facilitate commercialization apply to the SBIR process, too. Additionally, one sample SBIR contractor suggests that the Air Force return Phase II prototypes to the contractor. In some cases, the contractor cannot afford to build another prototype for its own use. Contractors use the prototypes to demonstrate their technology to potential investors and to conduct further development.

Future Research

The results of this study present several follow on research questions. First, the results of this study need confirmation by using a different sample from the same CRDA and SBIR populations. This study attempts to control for extraneous influences on the commercialization result by limiting sampling to one technology area. However, after discovering the diverse conditions within this technology area this researcher concludes that a larger sample across technology areas would not be unduly hindered by the differences in their respective markets. Additionally, this study does not address the time

factor involved in developing technologies. Those technologies promising commercialization today may fade with tomorrow's developments, while others with less promise today may find substantial markets in the future. Reevaluation of the sampled projects and firms in the future may lend more insight to the commercialization process.

In addition to firm size, Joseph Schumpeter, posited that firms with diverse products and high barriers to entry in their markets better utilized technology innovations. Examining these two factors in light of government involvement in technology transfer and commercial innovation efforts is warranted. One sample CRDA partner articulated the need for greater monopoly power to entice private firms to commit significant capital for the development of Air Force technology. While this study examines the maturity of technology from the perspective of applying it to the technology area of the innovation and the firm's experience in that technology area, exploring the firms experience in the area from which the innovation arose would provide a more complete examination of Schumpeter's firm diversification factor.

Finally, complete examination of government technology innovation processes requires better measures of outcomes. The measurement employed by this study, the degree of commercialization, only describes a level of development without allowing for quantification of results for the purpose of comparisons. For instance, a firm aggressively pursuing a development project that ultimately fails to commercialize may contribute more in terms of jobs, investment expenditure, or knowledge gained than another firm that successfully commercializes a project with little development effort. A better measure of outcome should consider the benefits accrued to all parties in the process as well as the costs incurred.

Appendix A. Interview Guide

INTERVIEW GUIDE FOR TELEPHONE SURVEY OF COMMERCIALIZATION ACTIVITIES OF CRDA/SBIR PARTNERS

DATE________

TIME OF INTERVIEW________

I. IDENTIFICATION INFORMATION:

A. COMPANY NAME____

B. STREET ADDRESS____

C. CITY______________________________ D._____ E. ZIP_________

F. TELEPHONE____________________ G. FAX____________________

H. POC____

I. TITLE____

J. AGREEMENT TYPE____

K. DATE SIGNED____

II. HISTORICAL OPERATIONS INFORMATION:

A. FIRM ORIENTATION:

1. FIRM'S PRIMARY BUSINESS AT THE INCEPTION OF THE CRDA/SBIR? (e.g. PETROCHEMICALS, SOFTWARE DEVELOPMENT, ETC)

____

2. FIRM'S ORIENTATION AT THE INCEPTION OF THE CRDA/SBIR? (PLEASE INDICATE BY PERCENT IN EACH APPLICABLE CATEGORY)

a. R&D_________ b. MANUFACTURING_________

e. PROFESSIONAL SERVICES_________ d. RETAIL/WHOLESALE_________

f. OTHER (PLEASE COMMENT BELOW)

____

____

____

B. SIZE:

1. WHAT WAS THE APPROXIMATE SIZE OF YOUR FIRM (#FULL-TIME EMPLOYEES) WHEN YOUR FIRM ENTERED INTO THE CRDA/SBIR?

NUMBER OF EMPLOYEES________

2. AT THE INCEPTION OF THE CRDA/SBIR, PLEASE CLASSIFY YOUR FIRM USING THE FOLLOWING GOVERNMENT CONTRACT DESIGNATION (MARK ONE).

LARGE BUSINESS_____ SMALL BUSINESS_____
SMALL DISADVANTAGED BUSINESS_____

3. AT THE INCEPTION OF THE CRDA/SBIR, HOW MANY EMPLOYEES WERE DEDICATED TO WORK UNDER THE CRDA/SBIR?

NUMBER OF DEDICATED EMPLOYEES________

C. BUSINESS MIX:

1. WHAT WAS YOUR FIRM'S APPROXIMATE MIX (ESTIMATED PERCENTAGE SHOULD TOTAL TO 100%) OF BUSINESS BETWEEN R&D AND PRODUCTION (PRODUCTION MEANS PRODUCING SOMETHING FOR SALE, i.e. PRODUCT, PROCESS, SERVICE) AT THE INCEPTION OF THE CRDA/SBIR?

R&D_____% PRODUCTION_____%

2. WHAT WAS YOUR FIRM'S APPROXIMATE MIX (ESTIMATED PERCENTAGE SHOULD TOTAL TO 100%) OF BUSINESS BETWEEN THE GOVERNMENT AND THE PRIVATE SECTOR AT THE INCEPTION OF THE CRDA/SBIR?

GOVERNMENT_____% PRIVATE SECTOR_____%

D. MARKET SHARE:

1. AT THE INCEPTION OF THE CRDA/SBIR, DID YOUR FIRM POSSESS A MARKET SHARE OF A PRODUCT OR PRODUCTS TO WHICH THE CRDA/SBIR EFFORT COULD BE DIRECTED?

YES_____ NO_____

2. IF YES TO QUESTION 1, WHAT PERCENT OF THE MARKET SHARE DID YOUR FIRM POSSESS AT THE INCEPTION OF THE CRDA/SBIR?

MARKET SHARE_____%

3. IF YES TO QUESTION 1, PLEASE DESCRIBE THE PRODUCT OR PRODUCT AREAS

____

____

____

____

____

E. INNOVATION EXPERIENCE:

1. PRIOR TO ENTERING INTO THE SUBJECT CRDA/SBIR, HOW MANY TECHNOLOGY INNOVATION AGREEMENTS (AGREEMENT CAN BE IN ANY FORM THAT LEGALLY PERMITTED YOUR FIRM TO DEVELOP AND SELL A COMMERCIAL PRODUCT RESULTING FROM THE AGREEMENT, i.e. SBIR CONTRACT, GRANT, CRDA/SBIR, OTHER) HAD YOUR FIRM PARTICIPATED IN WITH THE GOVERNMENT?

NUMBER OF INNOVATIVE AGREEMENTS______

2. PRIOR TO ENTERING INTO THE SUBJECT CRDA/SBIR, HOW MANY TECHNOLOGY INNOVATION AGREEMENTS HAD YOUR FIRM PARTICIPATED IN WITH NON-PROFIT OR EDUCATIONAL INSTITUTIONS?

NUMBER OF INNOVATIVE AGREEMENTS______

3. PRIOR TO ENTERING INTO THE SUBJECT CRDA/SBIR, HOW MANY TECHNOLOGY INNOVATION AGREEMENTS HAD YOUR FIRM PARTICIPATED IN WITH OTHER PRIVATE FIRMS?

NUMBER OF INNOVATIVE AGREEMENTS______

4. PLEASE COMMENT BRIEFLY ON EACH AGREEMENT TYPE, SUBJECT AND RESULT.

____
____
____
____
____

F. BUSINESS EXPERIENCE:

1. HOW MANY YEARS R&D AND PRODUCTION EXPERIENCE DOES YOUR FIRM POSSESS IN THE SUBJECT TECHNOLOGY AREA PURSUED UNDER THE CRDA/SBIR?

NUMBER OF YEARS_____

2. AT THE INCEPTION OF THE CRDA/SBIR, HOW MANY EMPLOYEES DEDICATED TO THE CRDA/SBIR POSSESSED AN ADVANCED DEGREE?

NUMBER WITH ADVANCED DEGREES_____

G. MATURITY OF TECHNOLOGY:

1. PLEASE CATEGORIZE THE LEVEL OF RESEARCH AND DEVELOPMENT AT THE INCEPTION OF THE CRDA/SBIR FROM WHICH YOUR FIRM BEGAN WORKING WITH THE SUBJECT TECHNOLOGY. (CHOOSE ONE)

a. BASIC RESEARCH_____

b. EXPLORATORY RESEARCH_____

c. ADVANCED DEVELOPMENT_____

d. OTHER_____

III. TECHNOLOGY DEVELOPMENT:

A. WHAT PRODUCTS OR PROCESSES HAVE BEEN DEVELOPED AS A RESULT OF THE CRDA/SBIR?

1.____
2.____
3.____
4.____
5.____

B. HAVE YOU PRODUCED AND SOLD THE PRODUCT OR A PRODUCT RESULTING FROM THE PROCESS? (Y/N)

1._____ 2._____ 3._____ 4._____ 5._____

C. FOR COMMERCIALIZED PRODUCTS RESULTING FROM THE CRDA/SBIR:
WHO BUYS THE PRODUCT? WHAT DOES IT DO FOR THEM?
WHAT IS UNIQUE ABOUT THE PRODUCT?

PRODUCT1.____

PRODUCT2.____

PRODUCT3.____

PRODUCT4.____

PRODUCT5.____

____

____

____

____

D. FROM WHAT SOURCES YOUR FIRM SEEK OUTSIDE SUPPORT TO COMMERCIALIZE THE PRODUCT OR PROCESS? (CHECK ALL THAT APPLY)

VENTURE CAPITAL	1.____	2.____	3.____	4.____	5.____
LARGE CORPORATION	1.____	2.____	3.____	4.____	5.____
JOINT VENTURE	1.____	2.____	3.____	4.____	5.____
LICENSING AGREEMENT	1.____	2.____	3.____	4.____	5.____
DISTRIBUTION AGREEMENT	1.____	2.____	3.____	4.____	5.____
OTHER______________	1.____	2.____	3.____	4.____	5.____
NO HELP NEEDED	1.____	2.____	3.____	4.____	5.____
DON'T KNOW	1.____	2.____	3.____	4.____	5.____

E. ARE YOU MANUFACTURING THE RESULTING PRODUCT OR UTILIZING THE RESULTING PROCESS YOURSELF? (Y/N)

1.____ 2.____ 3.____ 4.____ 5.____

IF NOT, WHO IS? (COMMENT)

____

____

____

F. ARE YOU MARKETING THE RESULTING PRODUCT OR PROCESS YOURSELF? (Y/N)

1.____ 2.____ 3.____ 4.____ 5.____

IF NOT, WHO IS? (COMMENT)

____

____

____

G. ARE YOU FINANCING THE RESULTING PRODUCT OR PROCESS YOURSELF? (Y/N)

1._____ 2._____ 3._____ 4._____ 5._____

IF NOT, WHO IS? (COMMENT)

____

____

____

H. IF OUTSIDE SUPPORT IS REQUIRED TO DEVELOP COMMERCIAL PRODUCTS FROM THIS CRDA/SBIR, WHAT PROGRESS HAS BEEN MADE TO DO THIS? (INDICATE ONE CATEGORY MOST APPLICABLE)

AGREEMENT IMPLEMENTED	1._____ 2._____ 3._____ 4._____ 5._____
AGREEMENT SIGNED	1._____ 2._____ 3._____ 4._____ 5._____
WILL SIGN AGREEMENT	1._____ 2._____ 3._____ 4._____ 5._____
SEEKING AGREEMENT	1._____ 2._____ 3._____ 4._____ 5._____
NO PROGRESS	1._____ 2._____ 3._____ 4._____ 5._____

I. IF YOU ARE PRODUCING PRODUCTS RESULTING FROM THIS CRDA/SBIR, WHAT IS THE LEVEL OF PRODUCTION? (CHECK ONE)

HI-VOLUME	1._____ 2._____ 3._____ 4._____ 5._____
MODERATE	1._____ 2._____ 3._____ 4._____ 5._____
JUST STARTED	1._____ 2._____ 3._____ 4._____ 5._____

J. FOR PRODUCTS DEVELOPED UNDER THIS CRDA/SBIR, WHAT HAS BEEN YOUR TOTAL SALES TO DATE? (MILLIONS $)

0 - 1	1._____ 2._____ 3._____ 4._____ 5._____
1 - 5	1._____ 2._____ 3._____ 4._____ 5._____
5 - 10	1._____ 2._____ 3._____ 4._____ 5._____
10 - 25	1._____ 2._____ 3._____ 4._____ 5._____
25 - 100	1._____ 2._____ 3._____ 4._____ 5._____
100+	1._____ 2._____ 3._____ 4._____ 5._____

K. FOR PRODUCTS DEVELOPED UNDER THIS CRDA/SBIR, WHAT IS YOUR EXPECTED ANNUAL SALES FOR THE NEXT 5 YEARS? (MILLIONS $)

0 - 1	1._____	2._____	3._____	4._____	5._____
1 - 5	1._____	2._____	3._____	4._____	5._____
5 - 10	1._____	2._____	3._____	4._____	5._____
10 - 25	1._____	2._____	3._____	4._____	5._____
25 - 100	1._____	2._____	3._____	4._____	5._____
100+	1._____	2._____	3._____	4._____	5._____

L. FOR PRODUCTS DEVELOPED UNDER THIS CRDA/SBIR, WHAT IS YOUR PERCENT OF SALES TO THE GOVERNMENT v. PRIVATE SECTOR?

PRODUCT 1:	% GOVT SALES_____	% PRIVATE SALES_____
PRODUCT 2:	% GOVT SALES_____	% PRIVATE SALES_____
PRODUCT 3:	% GOVT SALES_____	% PRIVATE SALES_____
PRODUCT 4:	% GOVT SALES_____	% PRIVATE SALES_____
PRODUCT 5:	% GOVT SALES_____	% PRIVATE SALES_____

M. IF YOU HAVE SOLD A PRODUCT RESULTING FROM THIS CRDA/SBIR, WHEN WAS THE FIRST SALE?

DATE OF FIRST SALE____________________

IV. COMMENTS:

Appendix B. Data

	VARIABLE ONE:	VARIABLE TWO: FIRM SIZE		VARIABLE THREE: INNOVATION EXPERIENCE			VARIABLE FOUR TECHNOLOGY EXPERIENCE	VARIABLE FIVE: MATURITY OF TECHNOLOGY	DEPENDENT VARIABLE:
CASE NUMBER	CONTRACT TYPE	NUMBER OF EMPLOYEES	MARKET SHARE (%)	NUMBER OF GOVERNMENT INNOVATION AGREEMENTS	NUMBER OF PRIVATE INNOVATION AGREEMENTS	PRIVATE SECTOR SALES PERCENT OF TOTALSALES	NUMBER OF FIRM YEARS IN TECHNOLOGY AREA	RATING (1-4)	DEGREE OF COMMERCIALIZATION
1	SBIR	50	0	10	3	10	5	3	2
2	SBIR	40	0	40	0	40	2	3	2
3	SBIR	14	20	15	4	50	20	2	2
4	SBIR	4	0	6	4	0	1	2	3
5	SBIR	40	75	10	16	66	10	3	4
6	SBIR	1	0	0	1	0	8	3	2
7	SBIR	100	0	3	0	10	15	3	2
8	SBIR	50	0	10	3	10	5	3	1
9	SBIR	5	0	5	1	0	8	3	3
10	SBIR	65	0	110	13	30	10	3	3
11	SBIR	18	0	4	1	10	8	3	2
12	SBIR	10	0	19	0	0	3	3	2
13	SBIR	50	0	53	0	40	10	2	3
14	SBIR	15	0	0	0	10	10	3	2
15	SBIR	25	0	12	1	15	6	2	4
16	SBIR	50	0	27	5	50	26	3	2
17	SBIR	10	0	2	0	0	4	3	2
18	SBIR	2	0	5	3	40	3	2	2
19	SBIR	4	0	1	0	50	1	2	4
20	CRDA	9500	0	1	0	15	1	3	4
21	CRDA	55000	0	0	0	50	20	2	5
22	CRDA	55000	0	10	56	40	35	1	4
23	CRDA	150	0	10	12	15	17	2	5
24	CRDA	325000	0	5	145	98	15	2	4
25	CRDA	60	5	0	3	50	3	3	4
26	CRDA	50	0	20	7	15	3	2	3
27	CRDA	60	0	0	0	0	4	3	2
28	CRDA	45	50	2	2	0	2	2	5
29	CRDA	5	0	0	4	40	3	4	2
30	CRDA	14500	10	0	0	30	14	3	5
31	CRDA	1200	25	0	55	70	38	3	2
32	CRDA	39000	40	2	26	99	29	2	5
33	CRDA	450	15	0	15	10	23	3	1
34	CRDA	1000	0	0	2	10	0	4	5
35	CRDA	16	0	0	0	30	16	3	1
36	CRDA	1100	30	0	6	40	25	3	1
37	CRDA	200	50	1	3	80	25	3	2
38	CRDA	6	100	0	1	75	20	3	1
39	CRDA	150	0	10	12	15	17	3	5
40	CRDA	1500	10	0	0	20	10	3	5
41	CRDA	30	33	0	0	80	20	3	2
42	CRDA	60000	1	0	0	70	20	3	5

Appendix C. Multiple Regression Results

TWO-SAMPLE T TEST FOR DEGREE OF COMMERCIALIZATION BY AGREEMENT TYPE

TYPE	SAMPLE MEAN	SIZE	S.D.	S.E.
0	2.4211	19	0.9016	0.2068
1	3.3043	23	1.6358	0.3411

	T	DF	P
EQUAL VARIANCES	-2.10	40	0.0419
UNEQUAL VARIANCES	-2.21	35.3	0.0334

	F	NUM DF	DEN DF	P
TESTS FOR EQUALITY OF VARIANCES	3.29	22	18	0.0064

CASES INCLUDED 42   MISSING CASES 0

UNWEIGHTED LEAST SQUARES LINEAR REGRESSION OF THE INDEPENDENT VARIABLES, ABSOLUTE FIRM SIZE (SIZE), PRIVATE INNOVATION EXPERIENCE (PINNOV), TECHNOLOGY AREA EXPERIENCE (TECHEXP), AND THE MATURITY OF THE TECHNOLOGY (MAT1) AGAINST THE DEGREE OF COMMERCIALIZATION FOR THE SAMPLED SBIRs

PREDICTOR VARIABLES	COEFFICIENT	STD ERROR	STUDENT'S T	P	VIF
CONSTANT	3.43801	0.32141	10.70	0.0000	
SIZE	-0.00641	0.00647	-0.99	0.3416	1.3
TECHEXP	0.02397	0.02725	0.88	0.3964	1.5
PINNOV	-0.24802	0.10039	-2.47	0.0295	1.3
MAT1	-1.21474	0.33009	-3.68	0.0031	1.2

R-SQUARED	0.6183	RESID. MEAN SQUARE (MSE)	0.36675
ADJUSTED R-SQUARED	0.4910	STANDARD DEVIATION	0.60560

SOURCE	DF	SS	MS	F	P
REGRESSION	4	7.12846	1.78212	4.86	0.0146
RESIDUAL	12	4.40095	0.36675		
TOTAL	16	11.5294			

CASES INCLUDED 17   MISSING CASES 0

NOTE: Two cases removed (Case number five and number ten, SBIR data) because of outliers.

UNWEIGHTED LEAST UNWEIGHTED LEAST SQUARES LINEAR REGRESSION OF THE INDEPENDENT VARIABLES, ABSOLUTE FIRM SIZE (SIZE), TECHNOLOGY AREA EXPERIENCE (TECHEXP), AND THE MATURITY OF THE TECHNOLOGY (MAT) AGAINST THE DEGREE OF COMMERCIALIZATION FOR THE SAMPLED CRDAs

PREDICTOR VARIABLES	COEFFICIENT	STD ERROR	STUDENT'S T	P	VIF
CONSTANT	5.57329	1.67116	3.33	0.0037	
SIZE	4.304E-05	1.726E-05	2.49	0.0226	1.4
TECHEXP	-0.07585	0.02933	-2.59	0.0187	1.2
MAT	-0.53659	0.51120	-1.05	0.3078	1.4

R-SQUARED	0.4203	RESID. MEAN SQUARE (MSE)	1.83852
ADJUSTED R-SQUARED	0.3237	STANDARD DEVIATION	1.35592

SOURCE	DF	SS	MS	F	P
REGRESSION	3	23.9975	7.99916	4.35	0.0180
RESIDUAL	18	33.0934	1.83852		
TOTAL	21	57.0909			

CASES INCLUDED 22 MISSING CASES 0

NOTE: One case removed, (case number five from CRDA data in Appendix B) because of size outlier.

UNWEIGHTED LEAST SQUARES LINEAR REGRESSION OF THE INDEPENDENT VARIABLES, ABSOLUTE FIRM SIZE (SIZE), TECHNOLOGY AREA EXPERIENCE (TECHEXP), AND THE MATURITY OF THE TECHNOLOGY (MAT) AGAINST THE DEGREE OF COMMERCIALIZATION FOR THE SAMPLED CRDAs

PREDICTOR VARIABLES	COEFFICIENT	STD ERROR	STUDENT'S T	P	VIF
CONSTANT	6.70549	1.90342	3.52	0.0065	
SIZE	1.560E-06	3.154E-05	0.05	0.9616	2.4
TECHEXP	-0.04192	0.02899	-1.45	0.1821	1.3
MAT	-1.32044	0.62307	-2.12	0.0631	2.2

R-SQUARED	0.5080	RESID. MEAN SQUARE (MSE)	1.13536
ADJUSTED R-SQUARED	0.3440	STANDARD DEVIATION	1.06553

SOURCE	DF	SS	MS	F	P
REGRESSION	3	10.5510	3.51699	3.10	0.0820
RESIDUAL	9	10.2183	1.13536		
TOTAL	12	20.7692			

CASES INCLUDED 13 MISSING CASES 0

NOTE: Ten cases removed. One is removed as an outlier for size (Case number five from CRDA data in Appendix B). Six are removed due to questionable commercial intent (Cases 20, 21, 30, 32, 39, 40). Three are removed because the CRDA project was abandoned by one or both partners before the completion of the requirements of the agreement (Cases 28, 34, 42).

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Vita

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13. ABSTRACT (*Maximum 200 words*)

The government employs two significant mechanisms for promoting commercialization of new technology: Cooperative Research and Development Agreements (CRDAs) and Small Business Innovative Research (SBIR) contracts. Fundamental differences exist between a CRDA and a SBIR based on the sizes of the firms involved, the nature of their governing agreements, and other factors. The objective of this thesis is to determine if a significant difference in the innovative strength of businesses exists when factors such as firm size, agreement type and other firm attributes are considered. Sample data for this study was collected by a telephone survey from firms selected from the Air Force population of CRDAs and SBIRs for Fiscal Years 1991-1993. The design of the survey allows the researcher to determine the degree of commercialization of the firm's product resulting from their agreement with the Air Force. This determination is employed as a measure of the firm's innovative ability. This researcher found that the degree of commercialization differed significantly between the two contract mechanisms. Moreover, firm size possessed a negative relationship with the degree of commercialization for CRDAs. Additionally, the more mature the technology transferred under both SBIRs or CRDAs, the greater the degree of commercialization.

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